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Access to electricity and cooking solutions

Technical documentation

TALL SOM FORTELLER

Bjørn K Getz Wold, Frode Berglund, Astrid Mathiassen, Ole Sandvik, Per Schøning, Titus Mwisomba, Samwel Kawa, Jillahuma Mussa, Ângelo Intimane, Domingos Malate, Berta Nhambirre, Sandra Pinoca, Kristian Lønø, Anne Abelsæth, Signe Vrålstad and Dag Roll-Hansen.

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Preface

The Impact of Access to Sustainable Energy Survey (IASES) was implemented in Mozambique and Tanzania in a three-partite collaboration. In Tanzania, the IASES 2021/22 was implemented by the National Bureau of Statistics (NBS) and Statistics Norway (SSB) in collaboration with the Ministry of Energy (MoE), Tanzania Electric Supply Company (TANESCO), Rural Energy Agency (REA) and Energy and Water Utilities Regulatory Authority (EWURA). The survey was jointly funded by the Government of Tanzania and the Norwegian Agency for Development Cooperation (Norad) through Statistics Norway.

According to the Tanzania National Energy Policy 2015, availability, affordability, reliability and access to modern energy services are considered to be the key ingredients towards achieving desired socio-economic development in Tanzania. Access to sustainable energy is a critical issue with far-reaching impacts on communities, economies, and the environment. In today's world, energy is the backbone of development. It is essential for meeting the basic needs of people such as cooking, lighting and heating.

The main results from this survey is published [1] in an overall report and available from the NBS website: https://www.nbs.go.tz/uploads/statistics/documents/en-1706803129-The%202021-22%20Impact%20of%20Access%20to%20Sustainable%20Energy%20Survey%20-%20Main%20Report.pdf

In Mozambique, the IASES implementation was led by Instituto Nacional de Estatística (INE) and SSB. The main results from the IASES survey in Mozambique [2] are published by INE in Portuguese in August 2023 and available from their Website: RELATÓRIO DE ENERGIA _ AGOSTO 2023 - INE.

This document presents the technical approach for how to collect, process and publish data on the multi-tier household access to electricity and cooking solutions based upon the Energy Sector Management Assistance Program (ESMAP), a global knowledge and technical assistance program administered by the World Bank and presented in Beyond Connections: Energy Access redefined [3].

Statistics Norway, 6 September 2024

Lasse Sandberg

Abstract

The Impact of Access to Sustainable Energy Survey (IASES) 2021/22 was implemented in Mozambique and Tanzania in a three-partite collaboration between Instituto Nacional de Estatística (INE) in Mozambique, the National Bureau of Statistics (NBS) in Tanzania and Statistics Norway (SSB) with consultations with the energy authorities in Mozambique and Tanzania. In each country a survey was jointly funded by the partner governments of Mozambique and Tanzania and the Norwegian Agency for Development Cooperation through Statistics Norway.

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank. Jointly with other global initiatives, the goals and targets for Sustainable Energy for All are presented in a Multi-Tier Framework (MTF). The MTF is presenting how to measure energy access in 5 tiers in the ESMAP 2015 report *Beyond Connections: Energy Access Redefined [3]*. This framework measures seven dimensions of the access to energy: capacity, duration, reliability, quality, affordability, legality, and health and safety, each in five tiers. Likewise, it measures six dimensions on access to modern cooking solutions: cooking emission exposure, cooking efficiency, convenience, safety, affordability and fuel availability in five tiers.

The three partners SSB, INE and NBS has extended this framework to cover the impact of energy access and energy efficient cooking solutions.

The framework on access to energy and modern cooking solutions building upon the survey instruments in Mozambique and Tanzania is presented in this document.

The survey results are presented in several reports available from the knowledge base for Development Cooperation in Statistics Norway Statistics Norway's development cooperation – SSB.

The main results from the IASES survey in Mozambique [2] are published by INE in Portuguese in August 2023 and available from their Website: RELATÓRIO DE ENERGIA _ AGOSTO 2023 - INE.

The main results from the survey in Tanzania are published by NBS [1] in English in November 2023 and available from their website: https://www.nbs.go.tz/uploads/statistics/documents/en-1706803129-The%202021-22%20Impact%20of%20Access%20to%20Sustainable%20Energy%20Survey%20-%20Main%20Report.pdf

Sammendrag

The Impact of Access to Sustainable Energy Survey (IASES) 2021/22 ble implementert i Mosambik og Tanzania i et treparts-samarbeid mellom Instituto Nacional de Estatística (INE) i Mosambik, National Bureau of Statistics (NBS) i Tanzania og Statistisk sentralbyrå (SSB) med konsultasjoner med energimyndighetene i Mosambik og Tanzania. I hvert land ble en undersøkelse i fellesskap finansiert regjeringene i Mosambik og Tanzania og det norske Utenriksdepartementet gjennom Statistisk sentralbyrå.

Det internasjonale initiativet om bærekraftig energi for alle, Energy Sector Management Assistance Program (ESMAP), et globalt kunnskaps og teknisk assistanse-program administrert av Verdens Banken og andre globale initiativ har presentert og utdypet målsettingen gjennom et Multi-Tier Framework (MTF). MTF presenterer hvordan man måler energitilgang i 5 nivåer i ESMAP 2015-rapporten Beyond Connections: Energy Access Redefined (Bhatia 2015). Dette rammeverket måler syv dimensjoner av tilgangen til energi: kapasitet, varighet, pålitelighet, kvalitet, rimelighet, lovlighet og helse og sikkerhet i fem tiers. På samme måte måler det seks dimensjoner for tilgang til moderne løsninger for ovner for matlaging: eksponering for utslipp fra ovner, effektivitet av ovner, sikker tilgang på energi, sikkerhet, rimelig kostnader og tilgang på drivstoff i fem tiers.

De tre partnerne SSB, INE og NBS har utvidet dette rammeverket til å dekke effekten av energitilgang og energieffektive ovner for matlaging.

Rammeverket for tilgang til energi og moderne ovner for matlagings bygger på spørreskjema og opplegg for undersøkelsene i Mosambik og Tanzania presentert i dette notatet.

Undersøkelsens resultater er presentert i flere rapporter tilgjengelig fra kunnskapsbasen for utviklingssamarbeid i Statistisk sentralbyrå Statistics Norway's development cooperation – SSB.

Hovedresultatene fra IASES undersøkelsen i Mozambique er publisert av INE på portugisisk i august 2023 og kan lastes ned fra deres nettsted: RELATÓRIO DE ENERGIA _ AGOSTO 2023 - INE.

Hovedresultatene fra undersøkelsen i Tanzania er publisert i en samlet rapport fra november 2023 [1] og tilgjengelig fra NBS-nettstedet: https://www.nbs.go.tz/index.php/en/census-surveys/energy-statistics/950-the-2021-22-impact-of-access-to-sustainable-energy-survey-main-report

Contents

1. International data standards for access to energy

The international standards for how to measure access to energy is based upon an extended classification of access to energy beyond, but based upon the Sustainable Development Goal number 7 and the targets:

- SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all and
- Target 7.1: By 2030, ensure universal access to affordable, reliable and sustainable energy services.

In order to provide information for the further development of national energy policies, the *Sustainable Energy for All* and other global initiatives have later elaborated the goal and the target in a Multi-Tier Framework, MTF. The MTF is presenting how to measure energy access in 5 tiers in the ESMAP (2015) report *Beyond Connections: Energy Access Redefined*. This report presents two frameworks for household energy access:

- Multi-tier framework for electricity
- Multi-tier framework for cooking

1.1. Multi-tier framework for electricity

The main approach in the framework for electricity is to measure the access to energy.

For grid-based electricity access to energy should be measured as the capacity of the grid connection. All grids are set up with alternating currency (ac) with a certain voltage. In the supply to communities this will be 340 volt. Usually the households receive 220 or 230 voltage, but in some countries only 110 or 120 voltage. The grid system will then allow each household to receive a maximum supply of electricity. The energy meter is regulated for a maximum amount such as 2000 W or 5000 W. The maximum supply is also regulated by the main fuses in the connection box. These are usually 20A, 50A, 64A or even 2 x 20A, 2 x 50A or 2 x 64 A. With a fuse of 20A, a grid-based connection with 220 volt ac gives a maximum of 220v x 20A = 4400W. It varies how the meters are marked, but all systems will have one or more fuse. In order to be sure to learn the capacity of a grid-based system, the survey is designed to collect information on both the main fuse(s) in xA and the meter limitation in xW. It is essential to capture at least one of these measures.

For solar based energy the energy should be measured as the capacity for daily delivery. During the day light, the limitation would be the capacity of the solar panel which is measured in W, such as 60W. The main use of solar power would however usually be the need for light during the night. The limitation would then usually be the capacity of the battery, but during the rainy season, a small panel may also be a limitation. Hence both the capacity of the panel and the capacity of the battery need to be captured. The capacity of the battery is usually given in Ah such as 20Ah or 140Ah assuming the energy is delivered as 12v direct currency (dc). It may however also be given Wh and then as 20Ah x 12v = 240Wh or 140Ah x 12v = 1680Wh. Hence the capacity of the battery may be given in either Ah or in Wh. This information is usually stamped on a metal label on the battery.

1.2. Multi-tier framework for cooking

The main energy use in a household is usually for heating in cold countries (such as in northern or high altitude/mountain countries) or for cooking in other countries. The efficiency of cooking solutions varies greatly from around 10-15 percent in open fireplaces to 70 percent in modern energy efficient cooking ovens. While the household may build their own fireplace or cooking oven or buy a cheap charcoal burner, the improved versions may cost like 10 – 50 US $ and only serve one pot.

The cooking and fireplace solutions may also have a health impact through smoke and soot. On the other hand, the fireplace may also serve to dry food and scare away mosquitos in the rainy season. Hence each household will find their own solution and it is important to document what kind of cooking solutions and cooking ovens are being installed and used.

There is a global data base with a huge range of ovens being tested, including for efficiency and indoor emissions. But in any country just a few of these are available. Hence for each country there is a need to identify the common types of cooking ovens according to efficiency and indoor emissions. Such a list will serve as a reference for the enumerators when doing the field work.

1.3. An overview of the multi-tier frameworks

Figure 1.1 Multi-Tier Framework for measuring access to electricity

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Capacity	Power capacity ratings (W or daily Wh)	**Less than 3 W**	At least 3 W	At least 50 W	At least 200 W	At least 800 W	At least 2 kW
		Less than 12 Wh	At least 12 Wh	At least 200 Wh	At least 1 kWh	At least 3.4 kWh	At least 8.2 kWh
	Services		Lighting of 1,000 lmhr per day	Electrical lighting, air circulation, television, and phone charging are possible			
Availability	Daily Availability	**Less than 4 hours**	At least 4 hours		At least 8 hours	At least 8 hours	At least 16 hours
	Evening Availability	**Less than 1 hour**	At least 1 hour	At least 2 hours	At least 3 hours	At least 4 hours	
Reliability		Not applicable	Not applicable	More than 14 disruptions per week	At most 14 disruptions per week or At most 3 disruptions per week with total duration of more than 2 hours"	(> 3 to 14 disruptions /week) or ≤ 3 disruptions /week with > 2 hours of outage	At most 3 disruptions per week with total duration of less than 2 hours
Quality		Not applicable	Not applicable	Household experiences voltage problems that damage appliances		Voltage problems do not affect the use of desired appliances	
Affordability		Not applicable for overall tiers, but as a separate measure	Not applicable for overall tiers, but as a separate measure	Cost of a standard consumption package of 365 kWh per year is more than 5% of household income	Cost of a standard consumption package of 365 kWh per year is less than 5% of household income		
Formality		Not applicable	Not applicable	No bill payments made for the use of electricity		Bill is paid to the utility, prepaid card seller, or authorized representative	
Health & Safety		Not applicable	Not applicable	Serious or fatal accidents due to electricity connection		Absence of past accidents	

Based upon Table 6.10 Multi-tier Matrix for Measuring Access to Household Electricity Supply [3]

Figure 1.2 Multi-Tier Framework for measuring access to modern energy cooking solutions

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Cooking exposure	Emission: Fuel	Firewood, dung, twigs, leaves, rice husks, processed biomass pellets or briquette, charcoal, kerosene				Biogas, ethanol, high quality processed biomass pellets or briquettes	Electricity, solar, LPG
	Emission: Stove Design	Three-stone fire, tripod, flat mud ring, traditional charcoal stove	Conventional or old generation ICS	ICS+ chimney, rocket stove or ICS + insulation	Rocket stove with high insulation or with chimney, advanced insulation charcoal stoves	Rocket stove with chimney (well sealed), Rocket Stove gasifier, Advanced secondary air charcoal stove, forced air	
	Ventilation: Volume of Kitchen	Less than 5 m³	More than 5 m³	More than 10 m³	More than 20 m³	More than 40 m³	Open air
	Ventilation: Structure	No opening except for the door	1 window	More than 1 window	Significant openings (large openings below or above height of the door)	Veranda or a hood is used to extract the smoke	Open air
	Ventilation level			Bad	Average		Good
	Contact time	More than 7.5 hours	Less than 7.5 hours	Less than 6 hours	Less than 4.5 hours	Less than 3 hours	Less than 1.5 hours
				Bad	Average		Good
Cookstove Efficiency	ISO's Voluntary Performance Targets (TBC)	Less than 10%	More than 10%	More than 20%	More than 30%	More than 40%	More than 50%
Convenience	Fuel acquisition (through collection or purchase) and preparation time (hours per week)		More than 7 hours	Less than 7 hours	Less than 3 hours	Less than 1.5 hours	Less than 0.5 hours
	Stove preparation time (minutes per meal)		More than 15 minutes	Less than 15 minutes	Less than 10 minutes	Less than 5 minutes	Less than 2 minutes
Safety of Primary Cookstove					Serious accidents over the past 12 months		No serious accidents over the past year
Affordability					Levelized cost of cooking solution (fuel) more than 5% of household income		Levelized cost of cooking solution (fuel) less than 5% of household income
Fuel Availability					Primary fuel available less than 80% of the year	Primary fuel is readily available 80% of the year	Primary fuel is readily available Throughout the year

Based upon Table 8.15 Multi-tier Matrix for Measuring Access to Cooking Solutions [3]

For both access to electricity and cooking solutions, the document makes a presentation in four steps as follows:

- First, the framework with dimensions and approach for tiers is presented.
- Second, the requirements for all tiers of all dimensions are presented.
- Third, the necessary data constructs are listed.
- Fourth and finally, the algorithms for calculations are presented.

2. Multi-tier household access to electricity

2.1. ESMAP framework for household access to electricity

The ESMAP framework for household access to electricity with dimensions and approach for tiers is presented in the Beyond Connection from ESMAP (2015) and summarized in figure 3 and table 6.10.

Figure 2.1 Multi-Tier Framework for Electricity

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Capacity		Capacity (from 3W to above 2kW) and ability to power appliances (applicable for off-grid solutions)				
Duration - day		From at least 4 hours a day to over 23 hours a day				
Duration - evening		From at least 1 hour in the evening to over 4 hours				
Reliability					Number and duration of outages	
Quality					Voltage problems do not affect the use of desired appliances	
Affordability				Basic service less than 5% of a household income		
Legality					Service provided legally	
Health and Safety					Absence of accidents	

Based upon Table 6.10 Multi-tier Matrix for Measuring Access to Household Electricity Supply [3] The overall tier level classification is determined by the lowest tier for which all applicable attributes are met

Figure 2.2 Multi-tier Matrix for Measuring Access to Household Electricity Supply

			Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
ATTRIBUTES	1. Peak Capacity	Power capacity ratings (in W or daily Wh)		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
				Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
		OR Services		Lighting of 1,000 lmhr/ day	Electrical lighting, air circulation, television, and phone charging are possible			
	2. Availability (Duration)	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
		Hours per evening		Min 1 hrs	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
	3. Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration <2 hrs
	4. Quality						Voltage problems do not affect the use of desired appliances	
	5. Affordability					Cost of a standard consumption package of 365 kWh/year <5% of household income		
	6. Legality						Bill is paid to the utility, prepaid card seller, or authorized representative	
	7. Health & Safety						Absence of past accidents and perception of high risk in the future	

Based upon Table 6.10 Multi-tier Matrix for Measuring Access to Household Electricity Supply [3], elaborating the approach to measure the access and classification into tiers for each dimension

2.2. Dimensions and tiers for household access to electricity

Dimensions for household access to electricity includes the following ones:

- Capacity – EL1: This dimension captures the power capacity of the energy source
- Duration - EL2: Capture availability, in terms of hours, of electricity in the household.
- Reliability - EL3: This dimension is relevant for grid only and captures how reliable the connection is.
- Quality - EL4: This dimension is relevant for grid only and captures the quality, in terms of voltage, of the connection.
- Affordability -EL5: Captures whether a household can afford a "standard level" of expenditure to electricity.
- Legality - EL6: This dimension is relevant for grid only and captures whether the household is legally connected to the grid.
- Health and Safety - EL7: This dimension is relevant for grid and electric generator only and captures health risk related to use of electricity in the households

Overall household Electricity access classification.
The tier level is determined by the lowest tier for which all applicable attributes are met. In the following we will explain the approach to classify the households in tiers in each of the dimensions.

2.3. Data constructs for dimensions and tiers of household access to electricity

Capacity – EL1

In order to measure the capacity of electric current we need to be precise in whether to measure current, voltage or power.

Figure 2.3 Measurement for grid current (AC or alternating current)

Current is measured in **amperes (A).** Amps measure current - how strong the current is. A modern TV may e.g. use 0.5 A, while a coffee maker may use 6A.

Voltage is measured in **volts (V)**. Simplified, we are talking about the potential of the energy, how much power you can get out. In a grid the socket at home gives you a voltage of 220 - 240 volts, while a battery adaptor may give you a voltage of 12 volts.

Power is measured **watts (W)**. Watt measures the **consumption of power** or how much power is being used at any point in time. Watt-hours measures the total consumption of power over a certain period of time. This is what you pay for when you buy electricity or pay the electricity bill. If you e.g. have used a new LED bulb of 5 watt for 6 hours, this will amount to 30 Wh or 0.030 kWh in consumption on your electricity bill.

If you want to know how much power your fuses can withstand at home, you can convert from amperes to watts using this formula: V x A = W

The standard voltage in the socket is 220-240 V, so if you have a fuse of 10A, you may use a load of up to 240V x 10A = 2400W. If you used the full potential during 2 hours, you consumed 2400W x 2hours = 4800Wh = 4.8 kWh.

Figure 2.4 Solar systems require measurement of power produced, stored and available

A **solar panel** may typically be able to produce a **potential of 12V**. A common solar panel may deliver **60w** in bright sunshine for something like **4 hours per day**.

The same formula applies, but may be turned around: A = W / V. Hence the solar panel may deliver 60W / 12V = 5A. Over 4 hours that amounts to 5A x 4 h = 20Ah per day and 7 days x 4 hours/day x 5A = 140Ah over a week.

That **current** may be stored in **a chargeable battery** with a **capacity** of up to **140 Ah**. Due to standard loss in charging and storage it may often take 2 weeks to load the battery.

A common sales-trick is to express the capacity in Wh giving a larger figure. Since the standard voltage of such rechargeable battery is typically 12V, the capacity may be given as Wh = Ah x V or **1680 Wh = 140 Ah x 12 V.** Hence a rechargeable battery with a capacity of 1680 Wh is equivalent to a rechargeable battery of 140 Ah**.**

Maximum energy effect. The standard approach for measuring capacity is to estimate the maximum effect of the system in the household in Watt (W or kW). This approach should be used for all kinds of grid connections and for electric generators. It may be used for solar panels if the peak capacity is given by the solar panel capacity.

Maximum amount of energy stored. For any type of energy supply limited by the amount of energy available within certain time period, the maximum amount of energy available to the household during 24 hours should be measured in Watthours (Wh or kWh). This approach should be used for all solar systems and any other system based upon energy stored in a battery or battery-bank. This would include all rechargeable batteries recharged outside the home. It may include solar home systems if the batteries are determining the peak capacity

Maximum consumption of energy. If the energy consumption is limited, the energy may be stored in built-in batteries and/or be supplied by integrated and small solar panels. In these cases, the capacity may be estimated by the type of services and appliances. This approach is only valid for households in low level tier, i.e. for Tier 1 and 2 capacity classifications.

Alternative 1, Maximum energy effect:
This alternative is relevant for grids, and fossil fuel generator. Capacity of the system is measured in W or kW. The actual capacity will be marked on the Fuse box, on the Energy meter, on the generator label. An alternative would be to check the main fuses. There is usually only one main fuse, but there may also be two or three. The fuse capacity should be multiplied with the voltage and hence a fuse of 20A gives a capacity of 20A x 230V = 4600W or 4.6 kW. Capacity is typically one fuse of 5, 20, 32, or 2 fuses of 2 x 25 or 2 x 32 A.

The questions in the surveys[1] that cover this information are:

- Grids: C26 (Enumerator should be instructed to check the fuse as an alternative).
- Mini-grids: Local mini-grids are not common in neither Mozambique nor Tanzania and not covered in general. As a proxy, respondents are asked whether they share a solar panel or generator with other households. See the next bullet point.
- Electric Generator Set: C91. (Answer should be in W (V x A is the same, but not common)

[1] The two questionnaires 4. Statistics Norway, N.B.o.S.-T., Instituto Nacional de Estatística - Mozambique, *Impact of Access to Sustainable Energy Survey (2019-2021) - Community Questionnaire*. 2019, Statistics Norway: Oslo, 5. Statistics Norway, N.B.o.S.-T., Instituto Nacional de Estatística - Mozambique, *Impact of Access to Sustainable Energy Survey (2019-2021) - Household Questionnaire*. 2019, Statistics Norway: Oslo. used for the IASES survey, the household questionnaire and the community questionnaire are both presented and may be downloaded from the Knowledge Platform for the Impact of Access to Sustainable Energy Survey (IASES) https://www.ssb.no/en/omssb/ssbs-virksomhet/statistikk-som-bistand/thematic-areas-of-support/knowledge-platform-iases

Tier Peak Capacity is defined in table 6.3 for W levels as follows: Tier 0, Tier1 3+, Tier 2 50+, Tier3 200+, Tier4 800+, Tier5 2000+

If a household has a backup-source the main supply will still determine the peak capacity.

Alternative 2, Maximum amount of energy stored
This alternative is relevant for solar home systems and rechargeable batteries as energy is stored. Capacity of the system is measured in watt-hours. The questions covering capacity for each system are:

- Solar-Home System: C56 - C59.
- Externally Recharged Battery: C123 – C125.

The maximum amount of energy from a solar home system is limited both by the maximum amount of energy delivered by the solar panels in a day and the storage capacity of the battery. The maximum amount of energy from the panel may be calculated as the peak capacity of the panel for 12 hours a day of sunshine. But since the sunshine is covered by clouds from time to time and moves across the sky from sunrise to sunset, while the solarpanel has a fixed angle, maximum charge will typically be 5 hours a day for a solar panel.

The batteries have a peak capacity which is usually printed on the battery label. For a new battery around 80% of this capacity is available for consumption. Over time this will be reduced to around 70%. Hence we may use 75% as an average.

Hence the capacities may be calculated as follows:

- Capacity of the solar panel C56(W) x 5hours = x Wh.
- Capacity of the 12V solar home system battery C57(Ah) x 12V x 75% = x Vah= x Wh.
- Capacity of the 12V solar home system is the minimum of the two previous capacity calculations.
- Capacity of the 12V externally recharged battery C123(Ah) x 12V x 75% = x VAh = x Wh.

Tiers are defined in table 6.3 for Wh levels as follows: Tier 0, Tier1 12+, Tier 2 200+, Tier3 1000+, Tier4 3400+, Tier5 8200+

If a household has a backup-source the main supply will still determine the peak capacity.

Alternative 3, Maximum consumption of energy:
As a last resort for households without proper information on neither available maximum energy effect nor information on maximum stored energy, the maximum consumption of energy may be estimated. Using information on electrical appliances available in the household and the average use of each appliance, capacity may be estimated.

This approach will be needed for households depending on energy is stored in built-in batteries and/or supplied by integrated and small solar panels. In these cases, capacity will not be stated on the devices and the capacity will be estimated by the type of services and appliances.

This approach may be used for other households where proper information on capacity is missing for some reason.

The report Beyond Connections, Energy Access Redefined is presenting an "Indicative Calculation of Electricity Consumption by Tier". The report has estimated the typical consumption of 17 appliances and bulbs and the typical number of hours used per day for households in each of the 5 tiers. Refer to appendix 1 for an overview.

Given the lack of information on actual time used per year and power consumption for each item we rather follow the simplified approach used in Rwanda and Ethiopia. It is based upon the same approach as in Beyond Connection, but in a simplified manner. For each household without any other proper information on capacity, the capacity level may be set according to appliances owned. The appliance requiring the maximum power will indicate the capacity level.

Figure 2.5 Ownership of appliances as a proxy for peak access to electrical power

Load level	Indicative electric appliances (at least one of these)	Capacity tier typically needed to power the level
No appliances		Tier 0
Very low load (3–49 W)	Task lighting, phone charging, radio	Tier 1
Low load (50–199 W)	As above + Multipoint general lighting, television, computer, printer, fan	Tier 2
Medium load (200–799 W)	As above + Air cooler, refrigerator, freezer, food processor, water pump, rice cooker	Tier 3
High load (800–1,999 W)	As above + Washing machine, iron, hair dryer, toaster, microwave TIER	Tier 4
Very high load (2,000 W or more)	As above + Air conditioner, space heater, vacuum cleaner, water heater, electric cookstove TI	Tier 5

Based upon Table 1 in Rwanda report [6]

This list is country specific and for each country, the actual list of appliances will have to be reviewed.

Alternative 4, Indicative calculation of electricity consumption by tier as a proxy for maximum consumption

Capacity is also limited by technology. If none of the other approaches above can be used to define capacity, it may be defined by technology as given in Table 6.3 [3] : Tier1: Solar Lantern, Tier2: Rechargeable Battery, SHS, Tier3: Medium SHS, fossil fuel-based generator, mini-grid, Tier4: Large SHS, fossil fuel-based generator, mini-grid, central grid, Tier5: Large fossil fuel-based generator, central grid.

Whereas solar lantern, grid and rechargeable battery technologies uniquely define the tier, fossil fuel and solar home systems can be defined in different tiers depending on the size of the system.

Based upon table 1 small/medium/large fossil fuel-based generators give 200W/800W/2000W. Based on the comparison in table 6.10 [3], this would be parallel to 1 kWh, 3.4 kWh and 8.2kWh.

With a solar home system, the maximum tier is tier 4. Still this would require both a decent solar panel capacity and a decent solar battery pack capacity. The solar panel capacity would be at least 170W and 680W. The required solar battery pack capacity would be 100 Ah and 400Ah.

Duration - EL2

Duration– day. EL2A

Duration in day and night (24 hours) is calculated from the question on number of hours electricity is available day and night. Household can have several sources and we define the total availability as max of hours electricity available from either main or backup source.

Duration – evening. EL2B

Duration in evening is defined by the question on number of hours electricity is available in evening. Household can have several sources and we define total availability as max of hours electricity available from either main or backup source.

Reliability. EL3
Reliability is defined by blackouts and duration of blackouts. Hence it may not be compensated by a back-up source. Reliability applies to the main power source for a grid connection.

Quality. EL4
Quality of electrical supply is defined in terms of voltage. It is relevant only for grids and mini-grids. Since these are not back-up source for each other, only information for the main source should be considered. The question we use is whether any appliances got damaged last 12 months due to voltage going up and down.

Affordability. EL5
Electricity is affordable if the cost of 365kWh/year from the grid is less than 5% of household income.

Legality. EL6
Legality is only relevant for grid and mini-grid, where it is possible to simply hook-up. This information can be difficult to get the respondent to reveal and we use the question on how the bill is paid. The connection is defined as legal if bill is paid to utility, prepaid card seller, or authorized representative (table 6.10).

Health and Safety. EL7
Health and safety is valid only for grid access. A positive indicator requires no serious accidents with permanent bodily injury.

Overall household Electricity access classification
The tier level is determined by the lowest tier for which all applicable attributes are met. In the calculation we have to make sure we treat the attributes not relevant for the respective households (e.g. if they only use SHS – legality and other attributes are not relevant)

- Tier0 - Tier5: Min (EL1, EL2A. EL2B, EL3, EL4, EL5, EL6, EL7, EL8)

2.4. Algorithms for data constructs for dimensions and tiers of household access to electricity

The actual classification of tiers for each dimension of household access to electricity is done by calculation of constructed variables. For the tier calculations, the range of all required constructed variables are serving as the base to identify the tiers. All SPSS program cuts are in green colour.

Two sets of variables are being constructed. The prefix AE denotes Access to Energy and the prefix AET denotes Access to Energy in Tiers:

Variable name	**Short explanation**
AECAPW	AEcapacityW
AEGCAPW	AEGridCapacityW
AESOLW	AEsolarCellCapacityW
AESOLWH	AEsolarCellCapacityWh
AESOBWH	AEsolarBatteryCapacityWh
AESOLAR	AESolarMinCellBattCap
AEAGGW	AEaggregateCapacityW
AEAGBATW	AEAggregatewBatteryCapacityW
AEBATWH	AEbatteryCapacityWh
AESOLLH	AEsolarLanternCapacityLmhr
AESERW	AEservicecapacityW
AEPEAK	AEPeakCapacity
AEDURDN	AEAvailability during day and night
AEDURN	AEAvailability during night
AEDUR	AEAvailability in total and by night.
AEREL	AEReliability
AEQUAL	AEQuality
AEAFF	AEAffordability
AECONSUM	AEConsumption
AEKWHCOSTS	AECostskWh
AEENERGYCOSTS	AEEnergycosts
AELEG	AELegality
AEHLTH	AEHealth

Based upon these variables, the tier-levels will be:

Variable name	**Short explanation**
AETCAPW	AETcapacityW
AETGCAPW	AETGridCapacityW
AETSOLW	AETsolarCellCapacityW
AETSOBWH	AETsolarBatteryCapacityWh
AETAGGW	AETaggregateCapacityW
AEAGBATW	AEAggregatewBatteryCapacityW
AETBATWH	AETbatteryCapacityWh
AETSOLLH	AETsolarLanternCapacityLmhr
AETSERW	AETservicecapacityW
AETSOLAR	AETsolarsystem
AETDURDN	AETAvailability during day and night
AETDURN	AETAvailability during night
AETDUR	AETAvailability in total and by night.
AETREL	AETReliability
AETQUAL	AETQuality
AETAFF	AETAffordability
AETLEG	AETLegality
AETHLTH	AETHealth
AETACCESS	AETAccessElectricity

The algorithms will usually set the constructed variable to the value "0" and then recode the value if certain requirements are met and set to missing if not applicable.

AEGCAPW – AEGridCapacityW - Peak Capacity -Power capacity ratings in W
AEGCAPW calculates the capacity of the available grid electricity. It will be 0 for all households with no access to grid electricity and for household for which the available level cannot be measured. A grid connection has a minimum capacity of 2000W. This capacity is enough to belong to the highest tier. Hence, we use this for all households with a grid connection, even if most have a substantially higher peak capacity.

```
COMPUTE AEGCAPW = 0.
*if electricity from grid set capacity to 2000W.
IF (C10=1) AEGCAPW =2000.
*define the tiers for grid electricity.
RECODE AEGCAPW INTO AETGCAPW (2000 THRU HI=5) (ELSE=0).
```

AESOLW – AesolarCellCapacityW - Peak Capacity - Power capacity ratings in W
AESOLW calculates the capacity of the solar cell panel(s). It will be 0 for all households with no solar home system and for household for which the available level cannot be measured.

```
COMPUTE AESOLW=0.
*if household do not know how many hhs that share the solar home system, set it to 2.
IF (C55=88) C55=2.
*if solar home system is used only by one household, and the power rating is within range.
IF (C10=3 AND C54=2 AND (C56 GE 20 AND Ch56 LE 900)) AESOLW =C56.
*If power rating is unknown set it to the minimum of solar panels for solar home systems
sold today being 60W.
IF (C56=88) C56=60.
*if solar home system is used only by more household, and the power rating is within range
Divide the power rating by nymber of households that share it.
IF (C10=3 AND C54=1 AND (C56 GE 20 AND G56 LE 900)) AESOLW = C56/C55.
*On average a solar cell panel will provide energy for 5 hours a day.
COMPUTE AESOLWH = AESOLW * 5.
*define the tiers for solar home systems
RECODE AESOLW INTO AETSOLW (3 THRU 49=1) (50 THRU 199=2)
(200 THRU 799=3) (800 THRU 1999=4) (2000 THRU HI=5) (ELSE=0).
```

AESOBWH AEsolarBatteryCapacityWh - Peak Capacity - Power cap. ratings in Wh
AESOBWH calculates the capacity of the battery for storing electricity. It will be 0 for all households with no solar cell battery and for household for which the available level cannot be measured.

On average the battery may deliver around 75% of the potential, hence the real capacity is 75% of the nominal capacity. Batteries are usually 12V, hence this level is used in no information is recorded.

```
COMPUTE AESOBWH=0.
*if Ah and V both are unknown set Ah to the smallest possible value, 20.
IF (C57 = 88 AND C58 = 88) C57=20.
IF (C10= 3 AND C57 GE 20 AND G57 LE 900 AND C57 NE 88 AND C58 GE 6 AND C58 LE 24)
AESOBWH = C57 * C58 * 0.75.
```

***If hh has solar home system as main source, Ah is within range, Volt is within range and Ah not unknown, then AESOBWH is Ah*V*75%.**
IF (C10= 3 AND ((C57 LT 20 OR C57 GT 900) OR (C58 LT 6 OR C58 GT 24)) AND C59 NE 88) AESOBWH = C59 * 0.75.
***If hh has solar home system as main source, Ah or V are unknown, but WH is within range, then AESOBWH is Wh*75%.**
IF (C10= 6 AND C124 GE 6 AND C124 LE 24) AESOBWH = C124 * 0.75.
***define the tiers for batteries**
RECODE AESOBWH INTO AETSOBWH (12 THRU 199=1) (200 THRU 999=2) (1000 THRU 3399=3) (3400 THRU 8199=4) (8200 THRU HI=5) (ELSE=0).

AETSOLAR - AETSolarCapacity - Peak Capacity across the solar cell panel and battery/batterypack.
The real capacity of a solar system is the minimum capacity of the solar cell and the solar battery. Capacity across the solar cell panel and battery/batterypack can not be compared directly, hence peak capacity can only be calculated at tier level.

COMPUTE AETSOLAR=MIN (AETSOLW, AETSOBWH).

AEAGGW – AEaggregateCapacityW - Peak Capacity - Power capacity ratings in W
AEAGGW calculates the capacity of the aggregate. It will be 0 for all households with no aggregate and set to a minimum level of 1000W if the available level cannot be measured.

COMPUTE AEAGGW=0.
***If don't know how many are sharing we set this to 2 since it is usually too demanding to share with more than 2.**
IF (C90 = 88) C90=2.
***If hh's main source is an aggregate that is used only by this household and capacity is within W range, use AEAGGW for the calculation.**
IF (C10= 4 AND C89 EQ 2 AND C91 GE 500 AND C91 LE 50000) AEAGGW = C91.
***If hh's main source is aggregate that is shared with other and capacity is within W range, use AEAGGW for the calculation divided by the number of users.**
IF (C10= 4 AND C89 EQ 1 AND C91 GE 500 AND C91 LE 50000) AEAGGW = C91/C90.
***Define the tiers for aggregate.**
RECODE AEAGGW INTO AETAGGW (3 THRU 49=1) (50 THRU 199=2) (200 THRU 799=3) (800 THRU 1999=4) (2000 THRU HI=5) (ELSE=0).

AEBATWH - AEbatteryCapacityWh - Peak Capacity - Power capacity ratings in Wh
Some households report a battery or battery bank as the main source for electricity. The battery bank may be charged through a neighbor with access to the grid, a large diesel or petrol aggregate or even a large solar cell package. AEBATWH calculates the capacity of the battery for storing the electricity and follows a similar approach as for households with their own source for producing the electricity. It will be 0 for all households with no battery for charging and for household for which the available level cannot be measured. On average the battery may deliver around 75% of the potential, hence the real capacity is 75% of the nominal capacity. Batteries are usually 12V, hence this level is used in no information is recorded.

COMPUTE AEBATWH=0.
***if Ampere and AEBATWH are unknown set Ah to 20 which is the lowest commercial value.**
IF (C123 = 88 AND C125 = 88) C123=20.
If V is unknown set it to 12, since this is the standard value.

IF (C124=88) C124=12.
If main source is battery or if aggregate is main and battery main back up, Ah is within range and not unknown, and V is within range, then calculate capacity by using Ah and V
IF (C10= 6 AND C123 GE 20 AND C123 LE 500 AND C123 NE 88 AND C124 GE 6 AND C124 LE 24) AEBATWH = C123 * C125 * 0.75.
IF (C10= 4 AND C11=6 AND C123 GE 20 AND C123 LE 500 AND C123 NE 88 AND C124 GE 6 AND C124 LE 24) AEBATWH = C123 * C125 * 0.75.
If main source is battery (or main back up with aggregate as main source) and Ah within range and not unknown and V outside range, assume that V=12 and use Ah to calculate capacity
IF (C10= 6 AND C123 GE 20 AND C123 LE 500 AND C123 NE 88 AND (C124 LTE 6 OR C124 GT 24) AEBATWH = C123 * 12 * 0.75.
IF (C10= 4 AND C11=6 AND C123 GE 20 AND C123 LE 500 AND C123 NE 88 AND (C124 LTE 6 OR C124 GT 24) AEBATWH = C123 * 12 * 0.75.
If main source is battery (or main back up with aggregate as main source) and Ah and V without range and not unknown, and AEBATWH within range, use AEBATWH for calculating capacity
IF (C10= 6 AND (C123 LT 20 OR C123 GT 500) AND (C125 GE 200 AND C125 =LE 6000) AND C125 NE 88 AND (C124 LT 6 OR C124 GE 24) AEBATWH = C125 x 0.75.
IF (C10= 4 AND C11=6 AND (C123 LT 20 OR C123 GT 500) AND (C125 GE 200 AND C125 =LE 6000) AND C125 NE 88 AND (C124 LT 6 OR C124 GE 24) AEBATWH = C125 x 0.75.
***Define the tiers for battery**
RECODE AEBATWH INTO AETBATWH (12 THRU 199=1) (200 THRU 999=2)
(1000 THRU 3399=3) (3400 THRU 8199=4) (8200 THRU HI=5) (ELSE=0).

AEAGBATW – AEAggregatewBatteryCapacityW - Peak Capacity - Power capacity ratings in both W and Wh

AEAGBATGW calculates the total capacity of the aggregate supplemented with a battery or battery pack. It will only have a value for households with both an aggregate as the main source and a battery pack as a back-up source. By logic, the capacity is given by the maximum capacity of these two devices throughout a period, but since the summarized capacity is given by the capacity of the aggregate, this will give even the joined peak capacity. The main advantage with the combination is the ability to provide electricity over time, such as duration during day and night of available electricity.

COMPUTE AEAGBATW=0.
***If don't know how many are sharing we set this to 2 since it is usually too demanding to share with more than 2.**
IF (C90 = 88) C90=2.
***If hh's main source is an aggregate that is used only by this household and capacity is within W range, use AEAGBATW for the calculation.**
IF (C10= 4 AND C11=6 AND C89 EQ 2 AND C91 GE 500 AND C91 LE 50000) AEAGBATW = C91.
***If hh's main source is aggregate that is shared with other and capacity is within W range, use AEAGBATW for the calculation divided by the number of users**
IF (C10= 4 AND C11=6 AND C89 EQ 1 AND C91 GE 500 AND C91 LE 50000) AEAGBATW = C91/C90.
***Define the tiers for aggregate.**
RECODE AEAGBATW INTO AETAGBATW (3 THRU 49=1) (50 THRU 199=2)
(200 THRU 799=3) (800 THRU 1999=4) (2000 THRU HI=5) (ELSE=0).

AESOLLH AEsolarLanternCapacityLmh - Peak Capacity - Power capacity ratings in Lmh
AESOLLH calculates the capacity of solar lanterns used by the household. It will be 0 for all households with no solar lantern.

COMPUTE AESOLLH=0.
IF ((C10=7 OR C10 =8) AND (C76 GE =1 AND C76 LE 4) AND C81 GE 1) AESOLLH= 150 x C76 x C81.
RECODE AESOLLH INTO AETSOLLH (1000 THRU HI=1) (ELSE=0).

AESERW – AeservicecapacityW - Peak Capacity – Summary requirements of appliances
The ownership of appliances and the need of electrical power for each appliance may serve a s proxy for the tier level of access. Refer to the table on *Indicative Calculation of Electricity Consumption by Tier* in Appendix 1. The table shows the necessary power for groups of appliances. Each level will also include the appliances listed at lower levels. AESERW calculates the capacity needs of the available electrical devices used by the household. It will be 0 for all households with no electrical devices and 1 if their only device is a cell phone and device with just one electrical bulb.

COMPUTE AESERW=0.
***For all sources do the following calculations.**
***If hh has mobile charger and/or an electric radio.**
IF (C10 GE 1 AND C10 LE 9 AND (L7 EQ 1 OR L8 EQ 1)) AESERW=49.
***If hh has 3 or more traditional light bulbs and/or 3 or more LED light bulbs and/or 3 or more any light bulbs and/or a fan and/or computer and/or tv.**
IF (C10 GE 1 AND C10 LE 9 AND (L9 EQ 1 OR L16 EQ 1 OR L18 EQ 1)) AESERW=199.
IF (C10 GE 1 AND C10 LE 9 AND (L20 GE 3 OR L21 GE 3 OR L22 GE 3)) AESERW=199.
***If hh has fridge and/or freezer and/or electric water pump.**
IF (C10 GE 1 AND C10 LE 9 AND (L10 EQ 1 OR L12 EQ 1 OR L19 EQ 1)) AESERW=799.
***If hh has microwave oven and/or washing machine.**
IF (C10 GE 1 AND C10 LE 9 AND (L11 EQ 1 OR L13 EQ 1)) AESERW=1999.
***If hh has air conditioner.**
IF (C10 GE 1 AND C10 LE 9 AND (L15 EQ 1)) AESERW=2000.
***Define tiers based on appliances.**
RECODE AESERW INTO AETSERW (0=0) (1 THRU 49=1) (50 THRU 199=2) (200 THRU 799=3) (800 THRU 1999=4) (2000 THRU HI=5) (ELSE=0).

AECAPW - AECapacityW - Peak Capacity across the means of access to electricity EL1
*The capacity of an electricity source is determined by either the current peak capacity in Watt or the stored capacity in Watthours, and since these can not be compared directly, the overall capacity can only be compared at tier level.

As stated the list of appliances can serve as a proxy for the overall capacity. Hence, we first calculate the capacity from the various sources of electrical power. If the list of appliances indicates a possible higher tier level, we use this proxy to adjust the overall tier level with one step upwards. In no information on the source of electricity is available, we use the proxy power rate.

AETCAPW compares the various measures of tier peak capacity and calculates the final capacity in tier 0-5.

COMPUTE AETCAPW=0.
COMPUTE AETCAPW=MAX (AETGCAPWS, AETSOLAR, AETAGGW, AETBATWH, AETAGBATW, AETSOLLH).
IF (AETSERW GT AETCAPW AND AETCAPW LT 4) AETCAPW=AETCAPW+1.

AEDUR - Duration, Availability EL2
Duration, Availability EL2 is based on availability of electricity during 24 hours (day and night) and availability during night time.

AEDURDN - Availability during day and night – Duration – day. EL2A
Duration during day and night-time is calculated from the question on number of hours electricity is available day and night from either main (C10) or backup source (C11). i.e. max of relevant in (C38, C75, C105, C121).

AEDURDN calculates the number of hours with access to electricity during day and night time. It will be 0 for all households with no access to electricity.

```
COMPUTE AEDURDN=MAX (C38, C75, C105, C121).
RECODE AEDURDN INTO AETDURDN (2 THRU 3=1) (4 THRU 7=2)
(8 THRU 15=3) (16 THRU 22=4) (23 THRU HI=5) (ELSE=0).
```

AEDURN Availability during night – Duration – night. EL2B
Duration in evening is calculated from the question on number of hours electricity is available at night-time from either main (C10) or backup source (C11). i.e. max of relevant in (C39, C76, C106, C122).

AEDURN calculates the number of hours with access to electricity during night-time. It will be 0 for all households with no access to electricity.

```
COMPUTE AEDURN=MAX (C39, C76, C106, C122).
RECODE AEDURN INTO AETDURN (1=1) (2=2)
(3=3) (4 THRU HI=5) (ELSE=0).
```

AETDUR Availability – Duration – total and night. EL2
Overall duration is the minimum duration throughout combined day and night and at night compared with the requirements during total daytime + nighttime and by night.

Since there are different requirements, this constructed aggregate is only valid as a tier data construct.

```
COMPUTE AETDUR=MIN (AETDURDN, AETDURN).
MISSING VALUES AEDURDN AEDURN AEDUR AETDURDN AETDURN AETDUR (0).
```

AEREL Reliability. EL3
Reliability is defined by blackouts and duration of blackouts. Reliability applies only to the main power source for a grid connection only.

If grid connection, tier is at least 3. In number of blackouts is 14 or less, tier is 4. If number of blackouts is 3 or less and for a total of less than 2 hours, tier is 5.

```
COMPUTE AEREL=0.
IF (C10=1) AEREL=3.
IF (C10=1 AND C40 GE 1 AND C40 LE 14) AEREL= 4.
IF (C10=1 AND (C40 GE 1 AND C40 LE 4 AND C41 EQ 1) OR C40 EQ 66) AEREL= 5.
COMPUTE AETREL=AEREL.
MISSING VALUES AEREL AETREL (0).
```

AEQUAL – Quality – EL4

Quality of electrical supply is defined in terms of fluctuating voltage for grids. The question is whether any appliances got damaged last 12 months due to voltage going up and down.

Quality is measured for any household with national grid as the main source (C10=1)

COMPUTE AEQUAL=0.
IF (C10=1) AEQUAL=3.
IF (C10=1 AND (C45 = 2 OR C45=88)) AEQUAL=5.
COMPUTE AETQUAL=AEQUAL.
MISSING VALUES AEQUAL AETQUAL (0).

AEAFF – Affordability – EL5

Electricity is affordable if the cost of 365kWh/year is less than 5% of household income. Household income per year is defined in the consumption module. There are two alternatives of calculating the costs of 365kWh/year. The costs may be calculated from national prices on low level grid-electricity, or by calculating the average payment for prepaid electricity.

Consumption
***Clean all consumption variables by replacing 88, 888888, 8888888, 88888888 and Don't know with median value in each domain. Then run:.**
COMPUTE AECONSUM=(Q2A$1+Q2B$1+Q2C$1+ Q2A$2+Q2B$2+Q2C$2+Q2A$3+Q2B$3+Q2C$3+Q2A$4+Q2B$4+Q2C$4+Q2A$5+Q2B$5+Q2C$5+ Q2A$6+Q2B$6+Q2C$6+Q2A$7+Q2B$7+Q2C$7)*(365/7)+ (Q11+Q12+Q13+Q14)*(365/30) + Q15+Q16.
***If total consumption already calculated use this:.**
COMPUTE AECONSUM=HHExpAll.
MISSING VALUES AECONSUM (0).

Cost of 1kWh
COMPUTE AEKWHCOSTS = 0.
***The average costs are calculated for all who remember or have noted the last payment to the prepaid meter and amount of power purchased.**
IF (C27 = 1 AND C33 NE 88 AND C35 NE 88) AEKWHCOSTS = C33 / C35.
MISSING VALUES AEKWHCOSTS (0).

Total energy costs
***The energy costs of 365 kWh per year is a national value.**
COMPUTE AEENERGYCOSTS=365*AEKWHCOSTS * 100/ AECONSUM.
COMPUTE AEAFF=0.
IF (C10=1) AEAFF=3.
IF (AEENERGYCOSTS GT 0 AND AEENERGYCOSTS LE 5) AEAFF=5.
COMPUTE AETAFF = AEAFF.
MISSING VALUES AEAFF AETAFF (0).

AELEG - AELegality – EL6

Legality is only relevant for grid, where it is possible to simply hook-up. This information can be difficult to get the respondent to reveal and we use the question on how the bill is paid. The connection is defined as legal if bill is paid to utility, prepaid card seller, or authorized representative (table 6.10).

COMPUTE AELEG=0.

IF (C10=1) AELEG=3.
IF (C10 EQ 1 AND (C27 LE 1 OR ((C28 GE 1 AND C28 LE 10) OR C28 EQ 55)) AELEG=5.
COMPUTE AETLEG = AELEG.
MISSING VALUES AELEG AETLEG (0).

AETHLTH - AETHealth – EL7

Health and safety should be addressed for grid and electric generator.

Households are in tier 4-5 with no accidents and in tier 0-3 if there are accidents. Defined based on accidents with electrical system: (In last 12 months – any injuries or deaths due to the electrical technology). Defined in (C48) for grid and in C(110) for electric generator set. We are only asking the detailed questions for main power source. Hence only injures from main source would matter for tier classification.

COMPUTE AEHLTH=0.
IF (C10=1 AND C48=1) AEHLTH=3.
IF (C10=1 AND C48=2) AEHLTH=5.
IF (C10=4 AND C110=1) AEHLTH=3.
IF (C10=4 AND C110=2) AEHLTH=5.
COMPUTE AETHLTH=AEHLTH.
MISSING VALUES AEHLTH AETHLTH (0).

AETACCESS – AETAccess to electricity - Overall household Electricity access

The tier level is determined by the lowest tier for which all applicable attributes are met. In the calculation we have to make sure we treat the attributes not relevant for the respective households (e.g. if they only use SHS – legality and other attributes are not relevant)

Tier0 - Tier5: Minimum of EL1, EL2A, EL2B, EL3, EL4, EL5, EL6, EL7, EL8.

For many households one or more of these variables are missing. The data-statement should only compare the non-missing variables.

COMPUTE AETACCESS = 0.
COMPUTE AETACCESS=MIN (AETCAPW, AETDUR, AETREL, AETQUAL, AETAFF, AETLEG, AETHLTH).

3. Measuring Access to Household Cooking Solutions

The reference report *Beyond Connections: Energy Access Redefined [3]* presents seven dimensions on how cooking ovens contribute to a sustainable and clean access to energy. As for the access to electricity, each of these dimensions are measured and classified in tiers from 0 to 5.

An adapted table for the reference report presents the conceptual dimensions.

Figure 3.1 Multi-Tier Framework for Cooking solutions

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Indoor air quality		Concentration of PM2.5 and CO; tiers aligned with WHO guidelines				
Efficiency		Tier benchmarks under development, awaiting results of ISO process				
Convenience			Stove preparation time and fuel collection and preparation			
Safety			Absence of accidents and alignment with the ISO process			
Affordability					Levelized cost of cooking solution < 5% of household income	
Quality and availability of fuel					Cooking not affected by seasonal variations in fuel quality and availability	

Based upon Table 8.15 Multi-tier Matrix for Measuring Access to Cooking Solutions (Bhatia 2015)

The module on access to Household Cooking Solutions is designed to measure the 6 dimensions of the cooking related to dimensions from health impact to economic impact such as efficiency and convenience.

The global set of measurement dimensions is designed to serve any country based upon a multi-tier approach, each ranging from tier 0 to 5. Initially fuel quality was also included, but since the measurement of this need a technical survey at the local level, it is not included in the household survey. The final tier of access is determined by the lowest tier for any of the 6 dimensions. Emissions, indoor emissions and efficiency all ideally require professional measurement and analysis. The approach would then be to measure all types of ovens in a lab for emissions, indoor emissions and efficiency, store this information in a data-base <http://catalog.cleancookstoves.org/> and then record which of these ovens is used by each household. With such information plus information of time use, cooking area and accidents, the tier may be estimated for each household.

This ideal approach is designed for research on emission etc for each type of oven and is far too demanding for a survey. Hence for the current project, as well as for other national projects, a proxy system has been designed to serve the national users while it is still comparable with the global system as defined in *"Beyond Connections: Energy Access Redefined".*

3.1. Requirements for all tiers and dimensions for cooking solutions

The global database contains a large number of cooking ovens that has been tested by the producing companies and the technical team of the global data base. Still there is a need to supplement the database with cooking ovens which may be common in each country. The surveys on multi-tier access supported by the World Bank developed a simplified *Adapted Multi-Tier Framework for measuring access to modern energy cooking solutions* for countries like Cambodia, Rwanda and Ethiopia, using broader groups of stove design, fuel and ventilation.

This adapted version will serve as matrix for the Survey on Impact and Access to Sustainable Energy.

Figure 3.2 Adapted multi-tier framework for measuring access to modern energy cooking solutions

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Cooking Exposure	Emission: Fuel	Firewood, dung, twigs, leaves, rice husks, processed biomass pellets or briquette, charcoal, kerosene				Biogas, ethanol, high quality processed biomass pellets or briquettes	Electricity, solar, LPG
	Emission: Stove Design	Three-stone fire, tripod, flat mud ring, traditional charcoal stove	Conventional or old generation ICS	ICS+ chimney, rocket stove or ICS + insulation	Rocket stove with high insulation or with chimney, advanced insulation charcoal stoves	Rocket stove with chimney (well sealed), Rocket Stove gasifier, Advanced secondary air charcoal stove, forced air	
	Ventilation: Volume of Kitchen	Less than 5 m^3	More than 5 m^3	More than 10 m^3	More than 20 m^3	More than 40 m^3	Open air
	Ventilation: Structure	No opening except for the door	1 window	More than 1 window	Significant openings (large openings below/ above door-height	Veranda or a hood is used to extract the smoke	Open air
	Alternative proxy: Ventilation level	Bad			Average	Good	
	Contact Time	More than 7.5 hours	Less than 7.5 hours	Less than 6 hours	Less than 4.5 hours	Less than 3 hours	Less than 1.5 hours
Cookstove Efficiency	ISO's Vol. Performance Targets (TBC)	Less than 10%	More than 10%	More than 20%	More than 30%	More than 40%	More than 50%
Conve-nience	Fuel acquisition (collection or purchase) and preparation time (h/w)	More than 7 hours		Less than 7 hours	Less than 3 hours	Less than 1.5 hours	Less than 0.5 hour
	Stove preparation time (minutes per meal)	More than 15 minutes		Less than 15 minutes	Less than 10 minutes	Less than 5 minutes	Less than 2 minutes
Safety of Primary Cookstove		Serious accidents over the past 12 months				No serious accidents over the past year	
Afford-ability		Levelized cost of cooking solution (fuel) more than 5% of household income				Levelized cost of cooking solution (fuel) less than 5% of household income	
Fuel Availability		Primary fuel available less than 80% of the year				Primary fuel is readily available 80% of the year	Primary fuel readily available throughout the year

Based upon Table 8.15 Multi-tier Matrix for Measuring Access to Cooking Solutions [3]

Country level adapted cook stove typology

Based upon these emission and efficiency level standards, the main types of cooking stoves in each country will be identified, classified and documented by photos in each country, using groups of stove design, fuel and ventilation. The project in Mozambique and Tanzania build upon the typology from Rwanda and Ethiopia, such as documented in the Rwanda report: Rwanda, Beyond Connection, Energy Access Diagnostic Report, Based on the Multi-Tier Framework beyond Connections (2018), Table 2 page 8, shown below.

Figure 3.3 Detailed description of draft cooking stove typology

Type of fuel	Description of level	Tier
Firewood, dung, twigs and leaves	Three-stone, tripod, flat mud ring	0
	Conventional ICS (closed oven with separate openings for firewood etc and pots)	1
	ICS with Chimney (as convential ICS plus chimney), rocket stove with conventional material for insulation	2
	Rocket stove with high insulation, rocket stove with chimney (not well sealed)	3
	Rocket stove with chimney (well sealed), rocket stove gasifier (rocket stove with two chambers, one for firewood and one for the burning gas), batch feed gasifier (burning solid fuel which is added to the burning chamber in batches)	4
Charcoal	Traditional charcoal stoves	0
	Old generation ICS (with open chamber for charcoal)	1
	Conventional ICS(closed oven with separate chambers and openings for charcoal and pots)	2
	Advanced insulation charcoal stoves, kerosene oven	3
	Advances secondary air charcoal stoves (tightly closed burning chamber with controlled entry of air)	4
Rice husks, pellets and briquettes	Natural draft gasifier (only pellets and briquettes)	3
	Forced air	4
LPG and biogas, electricity (grid or solar), solar oven (non-electric)		5

Based upon the frame presented in Table 8.8 Multi-tier Framework for Indoor Air Quality Measurement [3] adapted to situation in Tanzania and Mozambique

ICS: Improved Cooking Stove. To develop such table for a new country, the national statistical office will have to work with specialists on cooking stoves in order to identify a national typology and photos presenting each type. It is essential to work with specialists both linked to official agencies and to national and international NGOs operating in the country. Improved Cooking Stoves (ICS) will be identified and classified according to efficiency. The list of ovens presented on the next page builds upon reports by specialists in Tanzania [7] and Mozambique, and observations during the pretest.

Figure 3.4 Cooking ovens

Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Fuel: Firewood, dung, twigs and leaves					
					
101 Three-stone stove	102 Round mud stove	111 ICS w/ ceramic fire chamber 112 ICS w/ metal ring	121 Rocket stove 122 High traditional burned mud/clay stove	131 Lorena 1 Rocket stove w high insulation 132 Rocket stove metal w/internal chimney/ Canamakeivuguruye	141 Lorena 2 Rocket stove with well-sealed chimney 142 Metal rocket stove
Fuel: Charcoal or kerosene					
					
201 Traditional charcoal stove - Open access for air 202 Traditional raised charcoal stove	211 Charcoal stove, Old ICS Opening for air may be closed	221 Ceramic lined charcoal ICS	231 Ceramic lined and insulated charcoal ICS	233 Kerosene cooking stove (Mchina)	241 Efficient charcoal stove with controlled airflow
Fuel: Rice husks, pellets and briquettes			**Fuel: LPG and biogas, electricity (grid or solar), solar oven (non-electric)**		
					
331 Gasifier stove 332 Saw dust, risk husk gasifier stove	341 Jiko Safi Gasifier stove w/forced air & chimney	451 Biogas stove	452 Multiple LPG stove 453 Single LPG stove	461 Electrical stove 462 Electrical plates without oven 463 LPG/gas and electrical stove	471 Solar cooker (Non-electric)

The approach for collecting information on the available ovens is to start with the fuel types. For each type of fuel, the pictures of ovens with the explanatory text will be used to identify the type of oven.

The next step will be to identify which of these are the main oven.

Please find a one-page list of the fuel and stove alternatives on the next page and a more detailed description annexed at the end of this document.

Be aware that since most of the detailed information is only provided for the main oven, detailed tabulated information on cooking ovens will only cover information for main ovens.

3.2. Data constructs for all tiers and dimensions of cooking solutions

In addition to the type of cooking stoves, additional information is needed for several of the attribute dimensions listed in table 4.3 Multi-Tier Framework.

The following variables are needed:

CO1 Cooking Exposure

Variable name	**Explanation**
• From type of oven	Cooking Exposure - Emission: Fuel
• From type of oven	Cooking Exposure - Emission: Stove Design
• From type of oven	Cooking Exposure – Overall emission
• CO1DEXPFLOOR	Cooking Exposure - Ventilation: Size of floor in kitchen
• CO1DEXPKITCEILING	Cooking Exposure - Ventilation: Type of ceiling kitchen
• CO1DEXPKITHEIGHT	Cooking Exposure - Ventilation: Height of kitchen
• CO1DEXPKITVOL	Cooking Exposure - Ventilation: Volume of Kitchen
• Tier direct from variables	Cooking Exposure - Ventilation: Structure
• Tier direct from variables	Cooking Exposure – Ventilation Level
• Tier direct from variables	Cooking Exposure – Overall Ventilation Level
• CO1HEXPCTIME	Cooking Exposure - Contact Time
• CO1IEXPOSURE	Overall cooking exposure

CO2 Cooking Efficiency

• From type of oven	Cooking oven efficiency

CO3 Cooking Convenience

• CO3ACONVFUEL (h/w)	Convenience - Fuel acquisition (coll./ purchase) and prep. time
• CO3BCONVSPREP	Convenience – Stove-preparation time (minutes per meal)

CO4 Cooking Safety

• Tier direct from variables	Safety of Primary Cookstove

CO5 Cooking Affordability

• COCONSUM	Total consumption
• COFUELPAY	Actual pay for fuel
• COFUELCOST	Standardized level of fuel costs
• CO5COAFFORD	Affordability

CO6 Cooking Availability

• CO6COAVAIL	Fuel Availability

CO Cooking Solution

• Summarized at tier level	Overall cooking solution

3.3. Algorithms for data constructs for tiers and dimensions of cooking solutions

Based upon the variables required, the tier-levels will be calculated

Variable name	Explanation
• CO1ATEXPFUEL	Cooking Exposure - Emission: Fuel
• CO1BTEXPSTOVE	Cooking Exposure - Emission: Stove Design
• CO1CTEXPEMISSION	Cooking Exposure – Overall emission
• CO1DTEXPKITVOL	Cooking Exposure - Ventilation: Volume of Kitchen
• CO1ETEXPVENTSTR	Cooking Exposure - Ventilation: Structure
• CO1FTEXPVENTLEV	Cooking Exposure - Ventilation Level
• CO1GTEXPVENT	Cooking Exposure - Overall Ventilation Level
• CO1HTEXPCTIME	Cooking Exposure - Contact Time
• CO1ITCOOKEXP	Cooking Exposure
• CO2TEFFICIENCY	Cookstove Efficiency
• CO3ATCONVFUEL	Convenience - Fuel acquisition (collection or purchase) and preparation time (h/w)
• CO3BTCONVSPREP	Convenience – Stove-preparation time (minutes per meal)
• CO4TSAFETY	Safety of Primary Cookstove
• CO5TAFFORD	Affordability
• CO6TAVAIL	Fuel Availability
• COTCOOKINGSOL	Overall cooking solution

CO - Cooking Exposure

To estimate Cooking Exposure, the first step is to determine the tier for *emissions* for a household based on its main stove. Each stove that the household uses is classified based on a combination of the stove design and the primary fuel used with that stove.

The second step is to determine the *ventilation* for the cooking area, categorized by the location of the cooking activity. A household that prepares its meals indoors in an area with fewer than two openings (windows and doors) to the outside is classified as having poor ventilation. A household that prepares its meals indoors in an area with two or more openings is classified as having average ventilation.

And a household that cooks its meals outdoors or an open veranda is classified as having good ventilation. Ventilation mitigates the indoor air pollution that a household is exposed to by diluting the concentration of emissions from polluting fuels and expelling the pollutants from the cooking area.

The third step is to determine the contact time.

Households in Tier 0 for emissions remain in Tier 0 for Cooking Exposure if they have poor or average ventilation but move to Tier 1 if they have good ventilation. Households in Tiers 1–3 for emissions (using a traditional cookstove or ICS) move down one tier for Cooking Exposure if they have bad ventilation, remain in the same tier if they have average ventilation, and move up one tier if they have good ventilation. Households in Tier 4 for emissions remain in Tier 4 for Cooking Exposure if they have poor or average ventilation and move to Tier 5 if they have good ventilation. Households in Tier 5 for emissions remain in Tier 5 regardless of ventilation

Hence cooking exposure is composed of several sub-attributes related to emission, ventilation and contact time.

C01 Cooking Exposure -Emission

CO1AEXPFUEL - Emission fuel

Emission of fuel is done according to the main fuel being used, not considering the possibilities to switch fuel. I10 gives fuel for most used oven.

RECODE I10 INTO CO1ATEXPFUEL (101 THRU 241=3) (331 THRU 451=4) (452 THRU 471=5) (ELSE=0).

CO1BEXPSTOVE - Emission Stove design

If most used oven in I10 is electricity, solar cooker, LPG ovens = Tier 5. For other fuel, the stove design decides.

I10 gives main stove type. Three-stone, tripod, flat mud ring and Traditional charcoal stoves = Tier 0. Conventional or old ICS with no chimney = Tier 1. ICS with Chimney, rocket stove with conventional material for insulation = Tier 2. Rocket stove with high insulation, rocket stove with chimney (not well sealed) = Tier 3. Rocket stove with chimney (well-sealed), rocket stove gasifier, batch feed gasifier = Tier 4.

RECODE I10 INTO CO1BTEXPSTOVE (101,102,201,202=0) (111,112,211=1) (121,122,221=2) (131,132,231,233,331,332=3) (141,142,241,341=4) (451 THRU 471=5) (ELSE=0).

CO1CEXPEMISSION – Overall emission

The overall emission is given by the highest level of emission due to the fuel and the type of oven, which is the lowest tier level.

COMPUTE CO1CTEXPEMISSION=MIN (CO1ATEXPFUEL, CO1BTEXPSTOVE).

Cooking Exposure - Ventilation: Volume of the kitchen and Ventilation structure and level

CO1DEXPKITVOL - Cooking Exposure - Ventilation: Volume of Kitchen

The Volume of the kitchen and the Ventilation structure are captured in two sets of questions. I22 In the last 12 months, where did you normally cook with [STOVE] in the dry season? followed by I23 - I24 and I54 - I55 will capture cooking in areas with significant opening or even open air. For cooking in closed areas I46 - I53 will capture the volume of the room. I54 will capture the number of openings and I55 the ventilation. This first sub-dimension calculates the volume of the cooking area.

```
*Calculate floor squaremeter:
IF (I46 EQ 1) CO1DEXPKITFLOOR=I47*0.75*I47*0.75.
IF (I46 EQ 2) CO1DEXPKITFLOOR=I48*0.75*I49*0.75.
IF (I46 EQ 3) CO1DEXPKITFLOOR=I50*0.5*0.75*I50*0.5*0.75*3.14.
IF (I46 EQ 4) CO1DEXPKITFLOOR=I51*0.75*0.75.
*Calculate type of ceiling.
RECODE I52 INTO CO1DEXPKITCEILING (2,3=0.75) (ELSE=1).
*Calculate height under ceiling in meter.
RECODE I53 INTO CO1DEXPKITHEIGHT (1=0.75) (2=1.7) (3=2.55) (4=3.4) (5=4.25).
*Calculate total volume of the cookingarea.
COMPUTE CO1DEXPKITVOL=CO1DEXPFLOOR * CO1DEXPKITCEILING * CO1DEXPKITHEIGHT.
*Identify tiers.
IF (CO1DEXPKITVOL GE 5) COTEXPKITVOL=1.
IF (CO1DEXPKITVOL GE 10) COTEXPKITVOL=2.
IF (CO1DEXPKITVOL GE 20) COTEXPKITVOL=3.
IF (CO1DEXPKITVOL GE 40) COTEXPKITVOL=4.
IF (I22 GE 5) COTEXPKITVOL=5.
```

MISSING VALUES CO1DEXPKITVOL, COTEXPKITVOL (0).

CO1E CO1EEXPVENTSTR - Cooking Exposure - Ventilation: Structure

This second sub-dimension calculates the ventilation structure of the cooking area.

```
*Classify tiers according to number of doors/windows in the cooking area.
COMPUTE CO1ETEXPVENTSTR=0.
IF (I54 GE 1) CO1ETEXPVENTSTR=1.
IF (I54 GT 1) CO1ETEXPVENTSTR=2.
IF (I54 EQ 4) CO1ETEXPVENTSTR=3.
IF (I22 GE 4) OR (I24 EQ 1) CO1ETEXPVENTSTR=4.
IF (I22 GE 5) CO1ETEXPVENTSTR=5.
MISSING VALUES CO1ETEXPVENTSTR (0).
```

CO1F CO1FEXPVENTLEV - Cooking Exposure - Ventilation Level

This third sub-dimension calculates the ventilation level as an alternative to the ventilation structure for the cooking area. Ventilation level is coded from I54 and I55. No ventilation gives Tier 0-2, Large opening and/or fan = Tier 3, veranda, open air, hood, chimney = Tier 4-5

```
*Calculate ventilation into three tiers levels.
COMPUTE CO1FTEXPVENTLEV=0.
IF (I54 GE 2) CO1FTEXPVENTLEV=2.
IF (I54 EQ 4) CO1FTEXPVENTLEV=3.
IF (I55 EQ 3) CO1FTEXPVENTLEV=3.
IF ((I55 EQ 1) OR (I55 EQ 2)) CO1FTEXPVENTLEV=5.
IF ((I22 GE 4) AND (I22 LE 6)) CO1FTEXPVENTLEV=5.
IF (I22 GE 5) CO1FTEXPVENTLEV=5.
MISSING VALUES CO1FTEXPVENTLEV (0).
```

CO1G CO1GEXPVENT - Cooking Exposure – Overall Ventilation Level

This sub-dimension summarizes the ventilation across the ventilation structure and the ventilation level.

```
*Calculate overall ventilation as the maximum of the ventilation structure and ventilation
level.
COMPUTE CO1GTEXPVENT=0.
COMPUTE CO1GTEXPVENT=MAX (CO1ETEXPVENTSTR, CO1FTEXPVENTLEV).
MISSING VALUES CO1GTEXVENT (0).
```

CO1H CO1HEXPCTIME - Cooking Exposure - Contact Time

Since the survey focuses on the most used oven, the contact time is measured for periods when that oven is used. Measured as cooking time from I37 to I40 = Tier 0 to 5.

```
COMPUTE CO1HEXPCTIME = 0.
COMPUTE CO1HEXPCTIME = (I37+I38+I39+I40) * 60.
COMPUTE CO1HEXPCTIME = 0.
IF (CO1HEXPCTIME GT 0 AND CO1HEXPCTIME LT 7.5) CO1HTEXPCTIME=1.
IF (CO1HEXPCTIME GT 0 AND CO1HEXPCTIME LT 6) CO1HTEXPCTIME=2.
IF (CO1HEXPCTIME GT 0 AND CO1HEXPCTIME LT 4.5) CO1HTEXPCTIME=3.
IF (CO1HEXPCTIME GT 0 AND CO1HEXPCTIME LT 3) CO1HTEXPCTIME=4.
IF (CO1HEXPCTIME GE 0 AND CO1HEXPCTIME LT 1.5) CO1HTEXPCTIME=5.
MISSING VALUES CO1HTEXPTIME (0).
```

CO1I CO1ICOOKEXP -Overall Cooking Exposure
The overall cooking exposure tier is determined by the lowest tier level for any of the sub-dimensions.

```
COMPUTE CO1ITCOOKEXP=0.
COMPUTE CO1ITCOOKEXP=MIN (CO1ATEXPFUEL, CO1BTEXPSTOVE, CO1CTEXPEMISSION,
CO1DTEXPKITCHEN, CO1GTEXPVENT, CO1HTEXPCTIME).
MISSING VALUES CO1ITCOOKEXP (0).
```

C01* Cooking Exposure - Alternative approach if missing information

In Rwanda and Ethiopia the detailed information such as on kitchen information and ventilation structure was missing for some households and a simplified approach was applied to determine the overall cooking exposure. This was based upon the tier for their cooking oven adjusted for ventilation (measured by the more rough indicator on ventilation being CO1FTEXPVENTLEV) and contact time, as follows:

- **For emissions Tier 5,** Cooking Exposure tier is 5.
- **For emissions Tier 4,**
- If ventilation tier is good, regardless contact time, Cooking Exposure tier is 5.
- For other cases, Cooking Exposure tier is 4.
- **For emissions Tier 3,**
- If ventilation tier is good and contact time is short, Cooking Exposure tier is 4.
- If ventilation tier is good and contact time is medium or long, Cooking Exposure tier is 3.
- If ventilation tier is average, regardless contact time, Cooking Exposure tier is 3.
- If ventilation tier is poor and contact time is short, Cooking Exposure tier is 3.
- If ventilation tier is poor and contact time is medium or long, Cooking Exposure tier is 2.
- **For emissions Tier 2,**
- If ventilation tier is good and contact time is short, Cooking Exposure tier is 3.
- If ventilation tier is good and contact time is medium or long, Cooking Exposure tier is 2.
- If ventilation tier is average, regardless contact time, Cooking Exposure tier is 2.
- If ventilation tier is poor and contact time is short, Cooking Exposure tier is 2.
- If ventilation tier is poor and contact time is medium or long, Cooking Exposure tier is 1.
- **For emissions Tier 1,**
- If ventilation tier is good and contact time is short, Cooking Exposure tier is 2.
- If ventilation tier is good and contact time is medium or long, Cooking Exposure tier is 1.
- If ventilation tier is average, regardless contact time, Cooking Exposure tier is 1.
- If ventilation tier is poor and contact time is short, Cooking Exposure tier is 1.
- If ventilation tier is poor and contact time is medium or long, Cooking Exposure tier is 0.
- **For emissions Tier 0,**
- If ventilation tier is good, regardless contact time, Cooking Exposure tier is 1.
- If ventilation tier is average or poor, regardless contact time, Cooking Exposure tier is 0.

```
COMPUTE CO1IEXPOSURE = 0.
IF (CO1BTEXPSTOVE EQ 5) CO1IEXPOSURE = 5.
IF (CO1BTEXPSTOVE EQ 4 AND CO1FTEXPVENTLEV EQ 5) CO1IEXPOSURE = 5.
IF (CO1BTEXPSTOVE EQ 4 AND CO1FTEXPVENTLEV NE 5) CO1IEXPOSURE = 4.
IF (CO1BTEXPSTOVE EQ 3 AND CO1FTEXPVENTLEV EQ 5 AND CO1HTEXPCTIME GE 3) CO1IEXPOSURE = 3.
IF (CO1BTEXPSTOVE EQ 3 AND CO1FTEXPVENTLEV EQ 5 AND CO1HTEXPCTIME GE 4) CO1IEXPOSURE = 4.
IF (CO1BTEXPSTOVE EQ 3 AND CO1FTEXPVENTLEV EQ 3) CO1IEXPOSURE = 3.
IF (CO1BTEXPSTOVE EQ 3 AND CO1FTEXPVENTLEV LT 3 AND CO1HTEXPCTIME GE 4) CO1IEXPOSURE = 3.
```

```
IF (CO1BTEXPSTOVE EQ 3 AND CO1FTEXPVENTLEV LT 3 AND CO1HTEXPCTIME LT 4) CO1IEXPOSURE = 2.
IF (CO1BTEXPSTOVE EQ 2 AND CO1FTEXPVENTLEV EQ 5 AND CO1HTEXPCTIME GE 4) CO1IEXPOSURE = 3.
IF (CO1BTEXPSTOVE EQ 2 AND CO1FTEXPVENTLEV EQ 5 AND CO1HTEXPCTIME LT 4) CO1IEXPOSURE = 2.
IF (CO1BTEXPSTOVE EQ 2 AND CO1FTEXPVENTLEV EQ 3) CO1IEXPOSURE = 2.
IF (CO1BTEXPSTOVE EQ 2 AND CO1FTEXPVENTLEV LT 3 AND CO1HTEXPCTIME GE 4) CO1IEXPOSURE = 2.
IF (CO1BTEXPSTOVE EQ 2 AND CO1FTEXPVENTLEV LT 3 AND CO1HTEXPCTIME LT 4) CO1IEXPOSURE = 1.
IF (CO1BTEXPSTOVE EQ 1 AND CO1FTEXPVENTLEV EQ 5 AND CO1HTEXPCTIME GE 4) CO1IEXPOSURE = 2.
IF (CO1BTEXPSTOVE EQ 1 AND CO1FTEXPVENTLEV EQ 5 AND CO1HTEXPCTIME LT 4) CO1IEXPOSURE = 1.
IF (CO1BTEXPSTOVE EQ 1 AND CO1FTEXPVENTLEV EQ 3) CO1IEXPOSURE = 1.
IF (CO1BTEXPSTOVE EQ 1 AND CO1FTEXPVENTLEV LT 3 AND CO1HTEXPCTIME GE 4) CO1IEXPOSURE = 1.
IF (CO1BTEXPSTOVE EQ 1 AND CO1FTEXPVENTLEV LT 3 AND CO1HTEXPCTIME LT 4) CO1IEXPOSURE = 0.
IF (CO1BTEXPSTOVE EQ 0 AND CO1FTEXPVENTLEV EQ 5) CO1IEXPOSURE = 0.
IF (CO1BTEXPSTOVE EQ 0 AND CO1FTEXPVENTLEV LE 3) CO1IEXPOSURE = 1.
MISSING VALUES CO1ITCOOKEXP (0).
```

3.4. COOKING EFFICIENCY

CO2 CO2EFFICIENCY - Cookstove efficiency

Cookstove efficiency includes combustion and heat-transfer efficiency. Direct measurement is difficult, thus rough and conservative estimates are adopted based on *primary* cookstove type [3] p.122. The general approach is, for each country, to identify typical cookstoves being commonly built on-site or available for purchase at the local market, and identify similar cookstoves already measured by the lab and listed in the [8]

For Rwanda and Ethiopia, the aim is to measure the efficiency combining fuel and stove type as follows:

- Tier 0 – Less than 10%
- Tier 1 – More than 10%
- Tier 2 – More than 20%
- Tier 3 – More than 30%
- Tier 4 – More than 40%
- Tier 5 – More than 50%

In Norway a scientific measurement of solid fuel efficiency gives large ranges as follows [9]:

- Open fire – 10 – 15%
- Ovens with separate fuel input, cooking ring and chimney – 30 – 70%
- Gasifying ovens – 70 – 80 %

Based upon the list of efficiency level above a proxy fuel/stove type list is being applied as follows:

Cooking stoves using firewood, dung, twigs and leaves:

- Tier 0 - Three-stone, tripod, flat mud ring
- Tier 1 - Conventional ICS (closed oven with separate openings for firewood etc and pots)
- Tier 2 - ICS with Chimney (as conventional ICS plus chimney), rocket stove with conventional material for insulation
- Tier 3 - Rocket stove with high insulation, rocket stove with chimney (not well sealed)
- Tier 4 - Rocket stove with chimney (well sealed), rocket stove gasifier (rocket stove with two chambers, one for firewood and one for the burning gas), batch feed gasifier (burning solid fuel which is added to the burning chamber in batches)

Cooking stoves using charcoal:

- Tier 0 - Traditional charcoal stoves
- Tier 1 - Old generation ICS (with open chamber for charcoal)
- Tier 2 - Conventional ICS(closed oven with separate chambers, separate openings for charcoal and pots
- Tier 3 - Advanced insulation charcoal stoves, kerosene oven
- Tier 4 - Advances secondary air charcoal stoves (tightly closed burning chamber with controlled entry of air)

Cooking stoves using pellets and briquettes
- Tier 3 - Natural draft gasifier (only pellets and briquettes)
- Tier 4 - Forced air

Cooking stoves using electricity or LPS, as well as solar cookers have an efficiency above 50% and are classified in Tier 5.

All information on fuel and type of cooking oven will come from **I10** for the oven most used.

RECODE I10 INTO CO2TEFFICIENCY (101,102,201,202=0) (111,112,211=1) (121,122,221=2) (131,132,231,233,331,332=3) (141,142,241,341=4) (451 THRU 471=5) (ELSE=0).

MISSING VALUES CO2TEFFICIENCY (0).

COOKING CONVENIENCE – COTCONV – Total convenience combining fuel acquisition and stove preparation

The classification of convenience is based upon time used to collect or purchase fuel and time for preparing the cookstove for each meal.

CO3A CO3ACONVFUEL - Convenience - Fuel acquisition and preparation time

- I43 How many times did the household gather, collect or purchase fuel during the last seven days?
- I44 How many members of the household were involved each time?
- I45 How much time did it typically take to gather, collect or purchase fuel per person each time they did so during the last seven days?

COMPUTE CO3ACONVFUEL=I43*I44*((I45HH*60+I45MM)/60).

CO3B CO3BCONVSPREP - Convenience – Stove-preparation time

Preparing the main stove is covered in *I34 How much time do household members spend preparing the [STOVE] and fuel for each meal on average.*
- I34 How much time do household members spend preparing the [STOVE] and fuel for each meal on average?

COMPUTE CO3BCONVSPREP=I34.

Convenience tiers is defined:
- Tier = 1
- If Fuel acquisition <7 & Stove preparation <15, Tier = 2
- If Fuel acquisition <3 & Stove preparation <10 Tier = 3
- If Fuel acquisition <1.5 & Stove preparation <5 Tier = 4
- If Fuel acquisition <0.5 & Stove preparation <2 Tier = 5

COMPUTE COTCONV=1.

IF (COCONVFUEL LT 7 AND COCONVSPREP LT 15) COTCONV=2.
IF (COCONVFUEL LT 3 AND COCONVSPREP LT 10) COTCONV=3.
IF (COCONVFUEL LT 1.5 AND COCONVSPREP LT 5) COTCONV=4.
IF (COCONVFUEL LT 0.5 AND COCONVSPREP LT 2) COTCONV=5.
MISSING VALUES CO3ACONVFUEL CO3BCONVSPREP (0).

CO10 COSAFETY - Safety of Primary Cookstove

Is related only to the *primary* cookstove. Questions used are: I41 In the last 12 months, did anybody in your household face any harm/injury from [STOVE]? and I42 Did you seek professional medical assistance for this injury?

COMPUTE COTSAFETY=0.
***If no serious accident clasify in tier4/5**
IF (I41 EQ 1) COTSAFETY=3.
IF (I41 EQ 2) COTSAFETY=4.
MISSING VALUES COTSAFETY (0).

CO5 CO5AFFORD - Affordability

According to ESMAP, p 121, the multi-tier framework considers cooking affordable if the levelized cost of a cooking solution is less than 5% of household income. Since fuel is needed throughout the year, it is reasonable to assume that the costs should be leveled across all household with the same type of oven. But at the same time we know that both quantity and price vary across households.

For all types of fuel, poor people may reduce costs by reducing the use of fuel. Hence the actual cost may be lower the levelized costs for all poor people, and especially poor rural people. Households using firewood as main fuel are asked whether collected or purchased firewood is their main fuel. The time spent for collecting and purchasing fuel is recorded and used for comparing overall costs. For all fuel, the fuel costs are cash expenses excluding the value of time spent on collecting or purchasing the fuel. The cash expenses for all fuel types collected are set to zero for calculation of affordability.

Based upon the ESMAP outline, the levelized costs is assumed to be average fuel costs for all household with the actual fuel. This will be based upon actual fuel costs in the household. For firewood, the leveled costs of firewood is calculated for firewood users buying the firewood.

A cost variable is estimated based upon charcoal use in urban areas. The NBS 2011-12 HBS estimates the use of charcoal to 94-180 kg per person per year for charcoal users. Assuming 5 persons in a household, that will be around 500 kg per year. The highest price will be in Dar es Salam and was around 45.000 to 70.000 TSh for a wholesale bag of 100 kg, indication a retail price of 500 TSh per kg. Hence the annual cost would be around 0.5 million TSh or $ 200. This temporary estimate of the fuel costs will be replaced by the average price within the complete data-set.

Household income per year is calculated using the consumption module, Q.

Consumption

***Clean all consumption variables by replacing 88, 888888, 8888888, 88888888 and Don't know with median value in each domain. Then run:.**
COMPUTE COCONSUM=0.
COMPUTE COCONSUM=(Q2A$1+Q2B$1+Q2C$1+
Q2A$2+Q2B$2+Q2C$2+Q2A$3+Q2B$3+Q2C$3+Q2A$4+Q2B$4+Q2C$4+Q2A$5+Q2B$5+Q2C$5+

Q2A$6+Q2B$6+Q2C$6+Q2A$7+Q2B$7+Q2C$7)*(365/7)+ (Q11+Q12+Q13+Q14)*(365/30) + Q15+Q16.
***If total consumption already calculated use this:.**
COMPUTE COCONSUM=HHExpAll.
MISSING VALUES COCONSUM (0).

Type of fuel is from I25. Costs of cooking is cost of buying fuel from I30 to I33.

The levelized costs will be estimated based upon the type of oven and the average price for fuel for all households in that group.

Figure 4.1 Levelized costs of fuel

Oven	Type of fuel	Type of fuel	Price from
101 – 142	Firewood	2, 3	I30 – I33
201 – 231, 241	Charcoal	4	I30 – I33
233	Kerosene, ethanol	5, 16	I30 – I33
331 - 341	Coal, briquettes	7, 11, 12, 14	I30 – I33
451	Biogas	15	I30 – I33
452 – 453, 463	LPG, gas	1, 6	I30 – I33
461 - 462	Electric	13	I30 – I33
471	Solar	18	0

The first step for calculation of levelized fuel costs is to calculate actual fuel costs for all households in each fuel group. The second step is to check for potential outlayers and recalculate levelized fuel costs based upon remaining households. The third step is to calculate levelized costs for each household based upon median costs for in each fuel-group.

The following leveled prices will be estimated based upon the final data-set:
LEVELPRICEWOOD, LEVELPRICECHAR, LEVELPRICEKERO, LEVELPRICEBRIQ, LEVELPRICEBIO, LEVELPRICELPG.
LEVELPRICEELEC will be set as average AEKWHCOSTS or LEVELKWHCOSTS.
LEVELPRICESOLAR will be set at 0.
If need be, the fuel groups may be combined.

***Calculate price of fuel for cooking per year.**
COMPUTE COFUELPAY=(I31/(I32*I33))*365.
***Calculate leveled fuel costs for each type of fuel.**
COMPUTE COFUELCOST=9999.
***Fuel collected is "free".**
IF (I25 EQ 8 OR I25 EQ 9 OR I25 EQ 10 OR I25 EQ 17) COFUELCOST = 0.
***Calculate costs of lpg, wood purchased, charcoal, kerosene, piped gas, coal, coal briquette, biomass briquette, pellets, biogas, ethanol.**
IF (I25 EQ 1 OR I25 EQ 2 OR I25 EQ 4 OR I25 EQ5 OR I25 EQ 6 OR I25 EQ 7 OR I25 EQ 11 OR I25 EQ 12 OR I25 EQ 14 OR I25 EQ 15 OR I25 EQ 16) COFUELCOST = (I31 / (I33*I32)) * 365.
***For users of electric ovens, calculate electricity costs of 1 kWh per day.**
IF (I25 EQ 13) COFUELCOST = AEKWHCOSTS.

***Calculate levelled costs.**
COMPUTE HHFREECOST=9999.
COMPUTE HHFIREWOODCOST=9999.
COMPUTE HHCHARCOALCOST=9999.
COMPUTE HHKEROSENCOST=9999.
COMPUTE HHBIOMASSCOST=9999.
COMPUTE HHBIOGASCOST=9999.

```
COMPUTE HHLPGCOST =9999.
COMPUTE HHELECCOST=9999.
*Free fuel.
IF (I25 EQ 3 OR I25 EQ 8 OR I25 EQ 9 OR I25 EQ 10 OR I25 EQ 17 OR I25 EQ 18) HHFREECOST =
COFUELCOST.
*Wood purchased
IF (I25 EQ 2) HHFIREWOODCOST = COFUELCOST or for now 500.
*Charcoal
IF (I25 EQ 4) HHCHARCOALCOST = COFUELCOST or for now 500.
*Kerosen, ethanol
IF (I25 EQ 5 OR I25 EQ 16) HHKEROSENCOST = COFUELCOST or for now 500.
*Coal, coal briquette, biomass briquett, pellets
IF (I25 EQ 7 OR I25 EQ 11 OR I25 EQ 12 OR I25 EQ 14) HHBIOMASSCOST = COFUELCOSTS or for
now 500.
*Biogas
IF (I25 EQ 15) HHBIOGASCOST = COFUELCOST or for now 500.
LPG, piped gas
IF (I25 EQ 1 OR I25 EQ 6) HHLPGCOST = COFUELCOST or for now 500.
*Electric
IF (I25 EQ 13) HHELECCOST = AEKWHCOSTS.
MISSING VALUES HHFREECOST HHFIREWOODCOST HHCHARCOALCOST HHKEROSENCOST
HHBIOMASSCOST HHBIOGASCOST HHLPGCOST HHELECCOST (9999).
*Calculate median levelled costs.
COMPUTE LEVELFREECOST=9999.
COMPUTE LEVELFIREWOODCOST=9999.
COMPUTE LEVELCHARCOALCOST=9999.
COMPUTE LEVELKEROSENCOST=9999.
COMPUTE LEVELBIOMASSCOST=9999.
COMPUTE LEVELBIOGASCOST=9999.
COMPUTE LEVELLPGCOST =9999.
COMPUTE LEVELELECCOST=9999.
AGGREGATE /OUTFILE=* MODE=ADDVARIABLES
 /LEVELFREECOST = MEDIAN(HHFREECOST)
 /LEVELFIREWOODCOST = MEDIAN(HHFIREWOODCOST)
/LEVELCHARCOALCOST = MEDIAN(HHCHARCOALCOST)
/LEVELKEROSENCOST = MEDIAN(HHKEROSENCOST)
/LEVELBIOMASSCOST = MEDIAN(HHBIOMASSCOST)
 /LEVELBIOGASCOST = MEDIAN(HHBIOGASCOST)
/LEVELLPGCOST = MEDIAN(HHLPGCOST)
/LEVELELECCOST = MEDIAN(HHELECCOST).

COMPUTE COLEVELAFFORD=0.
IF (LEVELFREECOST=0) COLEVELAFFORD = LEVELFREECOST * 100 / COCONSUM.
IF (LEVELFIREWOODCOST GT 0) COLEVELAFFORD = LEVELFIREWOODCOST * 100 / COCONSUM.
IF (LEVELCHARCOALCOST GT 0) COLEVELAFFORD = LEVELCHARCOALCOST * 100 / COCONSUM.
IF (LEVELKEROSENCOST GT 0) COLEVELAFFORD = LEVELKEROSENCOST * 100 / COCONSUM.
IF (LEVELBIOMASSCOST GT 0) COLEVELAFFORD = LEVELBIOMASSCOST * 100 / COCONSUM.
IF (LEVELBIOGASCOST GT 0) COLEVELAFFORD = LEVELBIOGASCOST * 100 / COCONSUM.
IF (LEVELLPGCOST GT 0) COLEVELAFFORD = LEVELLPGCOST * 100 / COCONSUM.
IF (LEVELELECCOST GT 0) COLEVELAFFORD = LEVELELECCOST * 100 / COCONSUM.
CO5TLEVELAFFORD=3.
IF (CO5LEVELAFFORD LE 5) CO5TLEVELAFFORD=5.
```

```
MISSING VALUES COLEVELAFFORD (0).
```

CO6 COAVAIL - Fuel Availability
Fuel availability is covered in question I28 (In the last 12 months, how often was the [FUEL TYPE] available?): Always available 1, Available 10-11 months 2, Available 9 months or less. 3, Rarely available 4.

We only use information *on primary fuel.* If hh uses secondary fuel because primary is not available, it is concluded that primary fuel in inadequate (p 123)

It should be acknowledged that we may miss fuel information for households using two ovens with different fuel.

```
COMPUTE CO6AVAIL=0.
COMPUTE CO6AVAIL=I28.
COMPUTE CO6TAVAIL=3.
IF (CO6AVAIL EQ 2) CO6TAVAIL=4.
IF (CO6AVAIL EQ 1) CO6TAVAIL=5.
MISSING VALUES CO6AVAIL (0).
```

3.5. Overall access to household cooking solutions

The tiers for overall cooking solution is summarized across the 6 cooking solution dimensions and is set by the lowest tier across these dimensions.

```
COMPUTE COTCOOKINGSOL = 0.
COMPUTE COTCOOKINGSOL = MIN (CO1ITEXPOSURE, CO2TEFFICIENCY, CO3ATCONVFUEL,
CO3BTCONVSPREP, CO4TSAFETY, CO5TAFFORD, CO6TAVAIL).
MISSING VALUES COTCOOKINGSOL (0).
```

Appendix A: Indicative Calculation of Electricity Consumption and Supply by Tier

The following table shows estimates of electricity consumption from the “Beyond Connections” report and preliminary project estimates of how many hours each appliance is used. As presented in the table, households in higher tiers are likely to use a given appliance for a longer period and hence use more kWh per year. Input data on ownership will come from section L household assets, questions on items L6-L22.

Figure A1 Indicative Calculation of Electricity Consumption by Tier

Appliance	Watt consumption	Hours per day	Annual consumption in kWh Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Electric traditional light bulbs	25	4/8/12	36.5	73	73	109.5	109.5
LED, Energy saving bulbs/ tubes	5	4/8/12	7.3	14.6	14.6	21.9	21.9
Phone charger	2	2/4	1.5	2.9	2.9	2.9	2.9
Radio	2/4	2/4	1.5	5.8	5.8	5.8	5.8
VCD/DVD	20	1		7.3	7.3	7.3	7.3
Fan	20	4/6/12/18		29.2	87.5	175.2	262.8
Refrigerator	300	6			657	657	657
Microwave oven	600	0.3			65.7	65.7	65.7
Hair dryer	300	0.3			32.9	32.9	32.9
Freezer	100	24			876	876	876
Washing machine	500	1			182.5	182.5	182.5
Electric sewing machine	50	1			18.3	18.3	18.3
Air Conditioner (AC)	1500	3					1642.5
Computer/ Tablet	20	1			7.3	7.3	7.3
Electric hot water pot/kettle	500	0.3			54.8	54.8	54.8
TV	20	2		14.6	14.6	14.6	14.6
Electric water pump	150	1			54.8	54.8	54.8

Based upon Table 6.13 Indicative Calculation of Electricity Consumption by Tier (Bhatia 2015)

Figure A2 Tiers of Capacity of Electricity Supply

TABLE 6.3

Tiers of Capacity of Electricity Supply

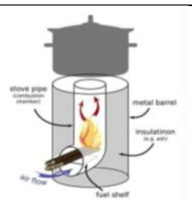
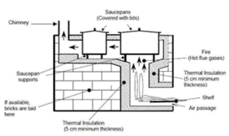
CAPACITY	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Power Capacity Ratings (minimum in W or daily Wh)		3 W	50 W	200 W	800 W	2,000 W
		12 Wh	200 Wh	1.0 kWh	3.4 kWh	8.2 kWh
Supported Appliances		Very low-power appliances	Low-power appliances	Medium-power appliances	High-power appliances	Very high-power appliances
Typical Supply Technologies		Solar lantern	Rechargeable battery, SHS	Medium SHS, fossil fuel-based generator, mini-grid	Large SHS, fossil fuel-based generator, mini-grid, central grid	Large fossil fuel-based generator, central grid

Based upon Table 6.3 Tiers of Capacity of Electricity Supply (Bhatia 2015)

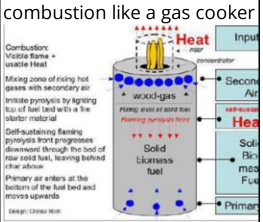
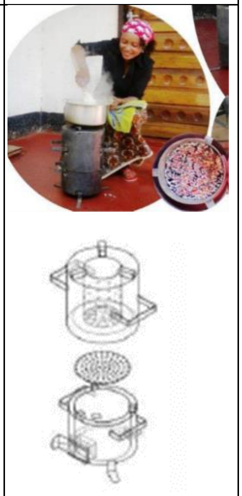
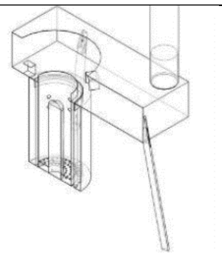
Appendix B: Multi-Tier Framework for cooking solutions

The list of cooking stoves are based upon solutions observed during the pilot survey and examples developed and presented by a number of energy development project such as presented at the Improved cookstoves colloquium in Nairobi in 2011 [7]

Figure B1 Multi-Tier Framework for cooking solutions

Fuel	Level	Tier				
Firewood, dung, twigs and leaves	Three-stone, tripod, flat mud ring	0	Separate openings for firewood and pots will usually raise the tier level to one, but not if there is only a mud ring on top. This type or ring may easily break.	 101 Three-stone stove	 101 Three-stone stove	 102 Round mud stove
	Conventional Improved Cooking Stove - ICS (closed oven with separate openings for firewood etc and pots)	1	Separate opening for firewood and pots with some stronger material to protect the opening	 111 ICS w/ ceramic fire chamber	 112 ICS with metal ring	 112 ICS with metal ring
	ICS with Chimney (as convential ICS plus chimney), rocket stove with conventional material for insulation	2	A Tier 2 rocket stove is a cooking stove designed to use small diameter firewood which are burned in a raised burning chamber, but not a double pipe.	 121 Rocket stove	 122 High traditional burned mud/clay stove	
	Rocket stove with high insulation, rocket stove with chimney (not well sealed)	3	A tier 3 rocket stove is a cooking stove designed to use small diameter firewood which are burned in a high temperature combustion chamber containing a vertical internal chimney which ensures almost complete combustion of the flames before reaching the cooking pot.	 131 Lorena 1 Rocket stove	 132 Rocket stove metal w/internal chimney (Canamakeivuguruye	
	Rocket stove with chimney (well sealed), rocket stove gasifier (rocket stove with two chambers, one for firewood and one for the burning gas), batch feed gasifier (burning solid fuel which is added to the burning chamber in batches)chamber in batches)	4	 A tier 4 rocket stove is a cooking stove designed to use small diameter firewood which are burned in a high temperature combustion chamber containing a vertical internal chimney and an external chimney	 141 Lorena 2 Rocket stove 	 142 Mozambique: Metal rocket stove	

Fuel	**Level**	**Tier**				
Charcoal & kero-sene	Traditional charcoal stoves	0	Traditional charcoal stove, no option for regulation of air	 201 Traditional charcoal stove Open access for air	 202 Traditional raised charcoal stove	
	Old generation ICS (with open chamber for charcoal)	1	An improved charcoal oven (old generation charcoal ICS) has the possibility to close or open air flow	 211 Charcoal stove, Old ICS	 212 Charcoal stove, Old ICS Opening for air may be closed	
	Conventional ICS with separate chambers and openings for air	2	A tier 2 charcoal oven has a ceramic lined burning chamber which gives some insulation higher temperature in the burning chamber and the possibility to close or open air flow into the oven	 221 Ceramic lined charcoal ICS	 222 Ceramic lined charcoal ICS (Mozambique)	
	Advanced insulation charcoal stoves, kerosene oven	3	A tier 3 charcoal ICS has an insulated ceramic lined burning chamber and the possibility to increase or reduce the air flow into the oven by partial or full closing	 231 Ceramic lined and insulated charcoal ICS	 232 Ceramic lined and insulated charcoal ICS	 233 Kerosene cooking stove (Mchina)

Fuel	Level	Tier				
	Advanced secondary air charcoal stoves (tightly closed burning chamber with controlled entry of air)	4	A tier 4 charcoal ICS has an insulated ceramic lined burning chamber and the possibility to regulate air flow into the oven	 241 Efficient charcoal stove with controlled airflow	 242 Efficient charcoal stove with controlled airflow	
Rice husks, pellets and briquettes	Natural draft gasifier (only pellets and briquettes)	3	A tier 3 Biomass gasifier stove pyrolyzes biomass to produce flammable pyrolysis gas (synthesis gas or wood gas) which is burning separately from the pyrolyzing biomass to create heat for cooking. By separating the flammable synthesis gases from the pyrolyzing biomass, the gases can be mixed thoroughly with air and burned to create a clean combustion like a gas cooker 	 331 Gasifier stove	 332 Saw dust, risk husk stove	 334 Jiko Bomba Gasifier stove
	Forced air	4	A tier 4 Biomass gasifier stove pyrolyzes biomass to produce flammable pyrolysis gas (synthesis gas or wood gas) which is burning separately from the pyrolyzing biomass to create heat for cooking. By separating the flammable synthesis gases from the pyrolyzing biomass, the gases can be mixed thoroughly with air and burned to create a clean combustion like a gas cooker. A tier 4 biomass oven has an external chimney and can regulate the amount of air entering the burning chamber	 341 Jiko Safi Gasifier stove w/forced air & chimney	 342 Jiko Safi Gasifier stove w/forced air & chimney	
LPG and biogas, electricity (grid or solar), solar oven (non-electric)		5	A Biogas or PPG gas oven has a separate gas container filled with biogas or LPG gas and one or more burners which may be regulated for small or large capacity	 451 Biogas stove	 452 Multiple LPG stove	 453 Single LPG stove

Fuel	Level	Tier				
		5	Electrical oven	 461 Electrical stove	 462 Electrical plates without oven	 463 LPG/ gas and electrical stove
		5	Solar stove (or cooker) is a device which uses heat in the sun radiation to cook or heat the food. To achieve higher temperatures required for cooking the radiation has to be concentrated. The three most common types of solar cookers are heat-trap boxes, curved concentrators (parabolics) and panel cookers1	 471 Solar cooker (Non-electric)	 472 Solar oven (noen-electric)	

Abbreviations

AE	Access to energy
Ah	Ampere-hour
ESMAP	Energy Sector Management Assistance Program
IASES	Impact of Access to Sustainable Energy Survey
ICS	Improved cooking solutions/stoves
kW	Kilowatt
kWh	Kilowatt-hour
LED	Light-emitting diode, light source
LPG	Liquefied petroleum gas
MoE	Ministry of Energy
NBS	National Bureau of Statistics
Norad	Norwegian Agency for Development Cooperation
REA	Rural Energy Agency
SDG7	Sustainable Development Goal number 7
SSB	Statistics Norway
TANESCO	Tanzania Electric Supply Company
TZS	Tanzanian Shilling
V	Volt
W	Watt
Wh	Watt-hour

Key Terms

Power plant – A production facility for electric power based upon sustainable production such as hydro-generated electricity, solar panel generated electricity, and windmill generated electricity; or diesel generated electricity.

Electric grid – Electric lines or wires capable of transmitting of electric charge at various levels from high to consumer voltage.

High voltage power transmission lines – Grid lines from power plants to community transformers from 147,000 to 1000 volts.

Transformer stations and transformers – Facilities reducing voltage step by step from the highest level at 147,000 volts to consumer levels at 220/230 V (consumer households) or 340 V (business consumers).

Connection to electricity – A household (or business) is connected to the electric grid by wires to the location.

Access to electricity – A household with their own connection to electricity, with the possibility to get connected to electricity or by gaining from neighbours connected to electricity, such as by being able to charge the mobile (for a fee).

Electric charge – The potential electric energy measured in volt or kilovolt abbreviated as V or kV.

Electric current or flow – The amount of electricity flowing in a circuit such as a wire. It is measured in ampere, abbreviated as A.

Electric power – The electric energy consumed such as for light or running a machine. It is measured in watts or kilowatts, abbreviated as W or kW. 1W=1V x 1A.

Electric power-consumption – The electric power consumed in a time period. It is measured in Wh or kWh.

Power capacity:

- From the grid there is no technical limitation. You pay per kW used in a time period in kWh.
- From a solar panel, there is electric energy limitation you usually get 95% of the panel capacity such as 19W from a 20W panel. You pay nothing and may consume for 10 hours during daytime in full sunshine.
- From a battery there is power limitation, you usually get 75% of the battery capacity. A 12V battery storing 20 Ah may give you 75% x 12V x 20Ah = 180 Wh. With a 20W solar panel you may theoretically recharge the battery in 1 day of full sunshine, but due to technical waste during charging, you may need 1.5 days. You may then light 2 x 5W LED bulbs for 18 hours or both 2 bulbs and a 20W TV for 6 hours.

Household – All members of a household living in one compound, one building, or one apartment and usually eating from the same pot.

Community – All households living in a village or a quarter where most households know each other and have a common knowledge or their location.

Region – The 26 official regions in Mainland Tanzania

Areas – In this report the communities are grouped in three levels of urban versus rural: Dar es Salaam, Other urban areas, and Rural areas.

Centrality – In this survey the rural communities and EAs are grouped in three levels of centrality: max 10 km to town, 11-25 km to town, more than 25 km to town.

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List of figures